

COMMAND AND STAFF SCHOOL

Volume V

OPERATIONS STAFF DIVISION

Part D. Air Weapons

Air Command and Staff College

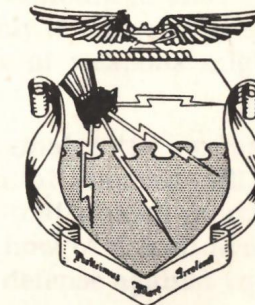
Air University

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December, 1954

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PREFACE

As an armed service, the Air Force has a major share of responsibility for our national survival. Aircraft can strike an enemy with greater speed, over greater distances, and with greater flexibility, efficiency, and economy than can be accomplished otherwise. Striking the enemy means delivering weapons.

This pamphlet on air weapons considers conventional explosive bombs and fuzes; aircraft guns and rockets; toxic gases, smoke, and incendiaries; biological warfare agents; and atomic weapons. Attention is focused on the characteristics of these weapons and on the factors that govern their employment. Some of the factors are specific, such as the type of weapon, method of delivery on the target, and probability of success. Other factors are less tangible, such as the morality or inhumanity of using the weapon, the probability of retaliation, and the psychological effect produced by the weapon.

During World War II Prime Minister Churchill and President Roosevelt announced that the Allies would use chemical weapons only if the enemy used them first. Thus, decisions on the use of weapons might be made at the highest level.

No weapon long remains the exclusive possession of a single nation. Potential enemies will, in all probability, develop any weapon that we can produce. Therefore every officer should know how to use all available weapons and to think in terms of defense against them.

To help you in your study, review questions appear at the end of each chapter. Answers to the review questions will be found at the back of the book.

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Selection of Aerial Bombs and Fuzes

AMONG the weapons available to the Air Force for striking the enemy on the ground and in the air are atomic bombs, which have already written world history. But atom bombs have not replaced aerial bombs using conventional explosives. Conventional explosive bombs, infinitely cheaper than atomic weapons and adequate for many purposes, are far from obsolete. True, many of the bombs used in World War II are obsolete, but it is improved design rather than the atom that has made them so.

Many factors affect bombing accuracy, but in this chapter we shall limit our study to the bombs themselves and their fuzes. Strategic bombing surveys of World War II indicate that often the striking power of a major Air Force unit was reduced by improper selection of bombs and fuzes. Even direct hits by improperly fuzed bombs caused little or no effective damage. Properly fuzed, these bombs would have destroyed the target. The vast combined effort required to place bombs on target demands a thorough analysis of weapons. Failure to consider all possible weapons and combinations of weapons can seriously weaken the potential of air power.

CONVENTIONAL BOMBS AND FUZES

IN A NONATOMIC BOMB, the weight and type of the explosive charge determine to a great degree the force of its blast pressure, blast impulse, and fragmentation velocity. The *charge-weight ratio* is the normal way of expressing the relationship between the weight of the explosive and the total weight of the bomb. The weight, dimensions, and shape of the bomb influence the load that a particular aircraft can carry, the dropping

characteristics of the bomb, and the ease with which it can be aimed.

Bombs procured by the Ordnance Corps (as distinguished from those procured by the Chemical Corps) are divided into two categories: high-explosive and fragmentation bombs.

1. High-Explosive Bombs

High-explosive (HE) bombs are those designed to carry the maximum explosive charge consistent with the penetrating strength of the case. They depend primarily upon blast for destructive effect. These bombs are divided into five principal types according to the strength of the case.

The light-case (LC) bomb carries the largest amount of explosive in relation to total weight. It has a charge-weight ratio of 80 percent. Because its light case cannot withstand impact, this bomb must be fuzed to detonate upon contact or before contact by means of a proximity (VT) fuze. It is available in a 4,000-pound size.

The general-purpose (GP) bomb can be used effectively against a variety of targets. It has a charge-weight ratio of 50 percent and a case heavy enough to permit penetration of fairly resistant targets. Because of this greater case strength, the bomb can be fuzed not only for instantaneous action and proximity detonation, but for various time delays ranging from a fraction of a second to 144 hours. Sizes of available bombs, in pounds, are 100, 250, 1,000, 2,000, and 4,000.

The semi-armor-piercing (SAP) bomb, which has a heavier case than the general-purpose bomb, is designed to penetrate 5 feet of concrete or 3½ inches of armor plate. The bomb has a charge-weight ratio

of about 30 percent and is available in 500- and 1,000-pound sizes.

The armor-piercing (AP) bomb is designed with an extremely heavy case which can penetrate 8 to 9 feet of reinforced concrete or an armor plate of considerable thickness. With its low charge-weight ratio of 14 percent, the bomb must reach a vital portion of the target before exploding. To insure penetration, the bomb must be dropped from a height that will give it the necessary striking velocity. To prevent ricochet, it must strike a flat surface.

Special weapons, which depend primarily upon high explosives for their destructive action, include the deep-penetration bomb, the depth bomb, the aerial mine, and the aerial torpedo.

Similar to the general-purpose bomb, the deep-penetration bomb has a charge-weight ratio ranging from 17 percent to 30 percent and is designed to be used against targets requiring deep penetration or high-order earth shock. Bombs are available in 12,000-, 25,000-, and 42,000-pound sizes.

The depth bomb is a light-case bomb having about a 70-percent charge-weight ratio. It is normally used with a hydrostatic fuze which can be set to function at a predetermined depth. The case of this bomb is designed with a flat nose to prevent ricocheting and has a predictable underwater trajectory. The bomb is available in 350-pound and 700-pound sizes.

The aerial mine is also a light-case bomb which is designed to sink to a predetermined depth, become active, and produce an effective underwater explosion. This missile is stabilized in flight by either a finned metal tail or a parachute which becomes detached upon impact with the water. These mines have a charge-weight ratio varying from 46 percent to 71 percent, depending upon the size and model, and are most commonly fuzed with magnetic or acoustic type fuzes. Bombs are available in 1,000-, 1,600-, and 2,000-pound sizes.

The aerial torpedo, similar to the torpedo launched from a submarine, can be launched from an aircraft traveling at an altitude of 1,800 feet and at a speed not in excess of 350 m.p.h. The charge-weight of

this 2,200-pound missile approximates 30 percent.

2. Fragmentation Bombs

Fragmentation bombs are designed to produce case fragments of the right number and size upon detonation. Little damage can be expected from blast effect because of the comparatively low charge-weight ratio. The fragmentation bomb is made up of a compressed helical spring wrapped closely around the seamless metal tube containing the high explosive. Nose and tail sections screwed into this body complete the assembly. Because the bomb must not be allowed to penetrate, which would reduce considerably the effectiveness of fragmentation, it is fuzed to detonate either on impact or above ground.

Fragmentation bombs are available in 20-, 23-, 90-, 120-, 220-, and 260-pound sizes. The 23-pound and the 120-pound bombs, called parafrags, are identical to the 20-pound and the 90-pound bombs, with the exception of a parachute which replaces the tail fins.

To provide increased stowage space in bomb bays of aircraft, the smaller sized fragmentation bombs are clustered. Known as the quick-opening type, these clusters open immediately upon release.

The butterfly, another type of fragmentation bomb, weighs 4 pounds and has a charge-weight ratio of about 13 percent. Designed primarily as an antipersonnel weapon, this bomb has three types of fuzes: one is actuated instantly on impact, another is actuated after a delay of 5 to 30 minutes, and the third is actuated by a disturbance of the bomb. Butterfly bombs are clustered in containers holding 24 or 90 bombs. Designed so that they can be aimed easily, these containers are of the delayed-opening type.

Many of the Air Force's high-explosive and fragmentation bombs have been redesigned in recent years, and several new bombs have been added to those just described. The new bombs, as well as the improved versions of the World War II types and a new kind of fuze, are described later in this chapter under "New Developments."

3. Types of Fuzes

A crucial part of every bomb is the fuze, the device that explodes the bomb at a set time. Fuzes are complex, and the Air Force has a great variety of them. They can be classified in a number of ways—for instance, according to their position in the bomb (in the nose or in the tail) or according to the manner in which they become armed (arming-pin or arming-vane types). A lengthy technical description of each of the many types of fuzes would not serve our purpose here. If you look at the problem of fuzes from the standpoint of the operations officer, all you want to know is what they do. We shall therefore classify them simply, according to where they make the bombs detonate: (1) above the target, (2) on the target, (3) in the target, (4) under the target, and (5) a long time after dropping.

WEAPONS FOR DIFFERENT TYPES OF TARGETS

THOROUGH KNOWLEDGE of structures (including buildings, bridges, and ships), industrial communication facilities, and military equipment is necessary to determine their vulnerability as targets and to predict the reaction of certain bomb-fuze combinations on them. The selection of the correct bomb-fuze combination is as important as the delivery of the bombs on the target. The goal of maximum results from minimum effort is attained by analyzing the target, selecting the proper bombs and fuzes, and considering all available weapons.

4. Buildings and Structures

The four main types of buildings, based on the characteristics of their construction, are the multistory wall-bearing building, the multistory frame building, the single-story steel frame industrial building, and the single-story reinforced concrete industrial building. Each type reacts differently to the action of the high-explosive bombs.

Multistory Wall-Bearing (Domestic, 3 to 5 Stories)

First choice: 4,000-lb. LC with instantaneous fuze
Alternates for structures—

30 to 35 ft. wide: 250-lb. GP with .25-sec. delay fuze

35 to 50 ft. wide: 500-lb. GP with .025-sec. delay fuze

50 to 80 ft. wide: 1,000-lb. GP with .025-sec. delay fuze

In each case the fuze is set to detonate the bomb at the level of, or just below, the second story from the roof. This delay will normally cause enough debris so that the lower floors will collapse from the excess weight. Any longer delay would allow complete penetration, and the full effect of the explosion would not be obtained. Buildings may be damaged so badly as to be uninhabitable and still not be completely demolished. Aerial photographs require careful evaluation, since damage under a roof cannot be seen and must be estimated. For this purpose, photographs taken at the time of the strike may reveal more than reconnaissance photographs taken later.

Multistory Frame (Steel or Reinforced Concrete skeleton)

First choice: 2,000-lb. GP with .025-sec. delay fuze

Alternates: 1,000-lb. GP with .025-sec. delay fuze

500-lb. GP with .025-sec. delay fuze

In general, exterior blast is not very effective against multistory frame buildings. Blast from large light-case bombs usually causes only localized damage. General-purpose bombs are much more effective, primarily because of their ability to penetrate to the interior of the building before detonating. They cause extensive damage both to the floors above and below the point of detonation and can also break or severely damage structural members. The multistory frame building is especially weak at the points where the beams and exterior columns are connected. The object of the .025-second delay is to obtain detonation at some point above the second floor and below the top floor, so that accumulated debris will cause overloading and collapse.

Single-Story Steel Frame Industrial Buildings

First choice: 4,000-lb. LC with instantaneous fuze

Alternates: 2,000-lb. GP with .01-sec. delay fuze

1,000-lb. GP with .01-sec. delay fuze

500-lb. GP with .01-sec. delay fuze

The degree to which this type of building is vulnerable is primarily dependent upon the live load which the frame is required to support. Such items as overhead cranes considerably increase the weight the structure must bear. Buildings with light steel frames which carry little live weight are vulnerable to blasts from larger bombs, whereas those buildings with traveling cranes can be destroyed by a general-purpose bomb. For best results, the general-purpose bomb should have a short-delay fuze that will actually damage the girders and structure.

Single-Story Reinforced Concrete Industrial Buildings

Less than 25 ft. in width: 500-lb. GP with .01-sec. delay fuze

25 ft. and more in width: 1,000-lb. or 2,000-lb. GP with .025-sec. delay fuze

The objective in attacking buildings of this type is to obtain a burst within the structure, because normally the concrete is not reinforced to withstand this. The size of the general-purpose bomb to be used depends upon the dimensions of the building. The selection of the fuze setting depends upon the thickness of the roof slab. It is desirable to get a burst sufficiently far below the roof so that a more moderate pressure is exerted over a wide area instead of a very high pressure over a small area.

Bomb-resistant structures are vulnerable to direct hits and near misses in much the same manner as small structures, except that the underground structure is more vulnerable to a burst alongside a wall. The weapon selected must be based on a knowledge of the vulnerability of the structure.

5. Underground Pipes

To destroy underground pipes, the burst must be at the level which will transmit maximum ground shock to the pipes. This type damage is important in such targets

as oil refineries, chemical factories, and railroad marshaling yards. At these targets, frost level is usually the factor that determines the depth the pipe is buried. In industrial areas water mains, buried electric cables, telephone and telegraph lines, and all such underground installations are highly desirable targets for bombing.

6. Manufacturing and Assembly Targets

Manufacturing and assembly targets include light industrial plants (automotive, aircraft, bearing, and chemical) generally housed in single-story structures of light or medium construction; heavy industrial plants (locomotive works, ordnance installations, and heavy machine tool factories); and multistory plants.

Structural Damage by High-Explosive Bombs

Single-story construction: 4,000 lb. LC with instantaneous or air-burst fuzing

Multistory or concrete frames: 500-lb., 1,000-lb., or 2,000-lb. GP with .025-sec. delay fuze

Structural Damage by High-Explosive and Incendiary Bombs

Single-story construction: 500-lb. GP with .01-sec. delay fuze

Multistory construction: 500-lb. GP with .025-sec. delay fuze

A small percentage of bombs with long-delay fuzes should be used to retard fire fighting and to destroy any firebreaks.

Where incendiary bombs alone can accomplish the desired destruction, 10 to 20 percent of the bomb load should consist of 100-pound general-purpose bombs with .01- or .025-second and long-delay fuzes. The general-purpose bombs assist in breaking through fire walls and prevent efficient fire fighting.

Combination Structural and Machinery Damage: Single-Story Construction. To attempt to destroy both the building and the equipment is not feasible unless very large bombs are used or the equipment consists of light or fragile machine tools. In plants with medium or heavy machine tools, the bomb should be selected to destroy either the building or its contents, whichever is

desired. To destroy medium-weight machine tools in factories where there are no blast walls, use a 1,000-pound general-purpose bomb fuzed to explode approximately three feet above the floor. If blast walls are known or suspected to be present, use a 2,000-pound general-purpose bomb or a 4,000-pound light-case bomb fuzed to explode approximately five or six feet above the floor.

Blast walls furnish efficient protection from small bombs unless a hit is scored on or beside the machine. Large bombs are necessary to overturn blast walls of brick or cement blocks with enough force to damage machines. An alternate choice for structures with or without blast walls is a 500-pound general-purpose bomb fuzed to crater in the floor and destroy the foundation of the machines.

Heavy machine tools (in heavy ordnance plants, steel mills, and shipyards) are likely to be very difficult to damage, and may be unprofitable targets. Only direct hits by general-purpose bombs of appropriate size can be expected to produce damage. A direct hit by a 500-pound general-purpose bomb may damage a 50-foot gun lathe, but a massive trip hammer or hydraulic press would probably require a direct hit with a 2,000-pound, or larger, general-purpose bomb. The most vulnerable point in this type of target is the bed, or foundation, of the tools. The size of bomb needed to destroy the bed by cratering varies with the nature of the particular target. For example, 1,000-pound general-purpose bombs fuzed to produce a maximum crater would be adequate for a 50-foot gun lathe in a heavy ordnance plant, but the tools in the rolling mill of a steel plant would require 2,000-pound or 4,000-pound general-purpose bombs fuzed for maximum crater.

Multistory, Wall-Bearing, Frame Structure. For this type of target, use the bomb-fuze combination best suited to give structural damage, since falling debris will cause most of the machinery damage.

7. Oil Targets

Oil targets include synthetic oil plants, oil refineries, and oil storage areas.

Synthetic Oil Plants and Oil Refineries

First choice: 500-lb. GP with .025-sec. delay and instantaneous fuzes

Alternates: 2,000-lb., 4,000-lb. GP with .025-sec. delay fuze

The vital portion of a synthetic oil plant is the section where the gas generator is located. Because of its shape and location, however, the gas generator may be extremely difficult to damage.

In an oil refinery, the shell- or pipe-type stills, fractionating towers, and catalytic cracking plants are but a few of its many vulnerable points. In choosing bombs, a compromise must be reached between using a large number to cover the whole area or using fewer but larger bombs to produce extensive damage around the point of impact. As oil plants often become covered with smoke early in the attack, the entire plant area, rather than a part of the plant, usually becomes the target. Because of the large amounts of exposed pipes, storage tanks, and other easily damaged equipment, a wide dispersal of bomb fragments is desirable. Earth shock from cratering bombs can break underground pipes. These factors indicate the desirability of using both instant and delayed fuzing, since bombs striking near, above, and below surface installations may cause appreciable damage.

Surface Storage Tanks. The objective in an attack of this kind is to rupture the tank shell and to ignite the contents. Fires are particularly advantageous. The heat from one burning tank will destroy tanks immediately adjacent by causing them to swell. Fragmentation damage is relatively ineffective against tanks because of the ease with which holes can be patched. Oil is difficult to ignite, but those liquids with higher boiling points, usually stored in spherical tanks, will flash upon sudden exposure to the atmosphere.

Underground Storage Tank. The bomb selected should be capable of penetrating the earth and concrete cover. Delay fuzes should be used to permit damage from either direct hits or near misses at the level of the tank.

8. Steel Mills

A steel mill is composed of coke ovens, blast furnaces, steel furnaces, and the blooming and rolling mills. In most plants, these four subplants are integrated so that they are mutually dependent. Crippling damage to any one will severely impair the operating efficiency of the rest.

Coke Ovens

1,000-lb. GP with .025-sec. delay fuze

The coke ovens are the most vulnerable portion of the entire steel plant. Since they are constructed of high-quality ceramic brick, they are relatively fragile. In addition, their reconstruction takes many months. The smallest bomb that can be relied upon for penetration is the 500-pound general-purpose bomb.

Blast Furnaces

500-lb. GP with .025-sec. delay fuze

Since the plan area of a blast furnace is relatively small and since a direct hit from a large bomb would be required to cause substantial damage, it is not normally advisable to attack this target with the object of complete destruction. Rather, it is more desirable to put it out of action by damage to such auxiliary equipment as cooling water systems, fans, and charging apparatus.

Steel Furnaces

250-lb. GP with .025-sec. delay fuze

Again, because steel furnaces have a small plan area, they are not considered the best target in the complex.

Blooming and Rolling Mills

2,000-lb. GP fuzed to produce maximum floor crater

Targets of this type are undesirable because it is difficult to destroy both the building and the equipment. See "Combination Structural and Machine Damage: Single-Story Construction" above.

9. Power Plants and Transformer Stations

If they can be damaged effectively, steam power plants, hydroelectric power plants, and transformer stations are choice targets

because they are the source of the power needed to operate most of the other industrial systems.

Steam Power Plants

500-lb., 250-lb. GP with .025-sec. delay fuze

Direct hits with bombs fuzed to explode within the boiler are most effective. Usually the damage from a near miss can be readily repaired. The bomb damage to a boiler, especially the high-capacity steam generator, is increased by the secondary damage caused by the sudden release of superheated steam and hot water. In addition, destruction of the turbines driving the electric power generators is facilitated by the fact that high rotational speed makes the turbine blades more susceptible to fragmentation damage. Short circuits within the electrical system at the bus bar can cause considerable destruction.

Hydroelectric Power Plants

Plants (unprotected): 250-lb., 500-lb. GP with .025-sec. delay tail fuze

Plants (protected): 500-lb., 1,000-lb. GP with 0.1-sec. delay tail fuze

Transformer Stations

250-lb. frag.; 250-lb., 5,000-lb. GP with instantaneous fuze

10. Dams

The vulnerability of a dam increases greatly with the height of the water behind the dam. For best results, then, bombing attacks should be made on a dam when the water level is highest.

Earth- and Rock-Filled Dams

12,000-lb., 25,000-lb., or 42,000-lb. deep-penetration bombs fuzed for maximum penetration

This type of dam can be most effectively damaged by cratering it at one point far enough below the surface to obtain sufficient head and volume of water to deepen the breach by erosion.

Concrete and Masonry Dams. The weight of the charge is obtained by using the following formula:

$$W = 0.43T^3$$

W is the weight in pounds, and T equals the thickness of the slab in feet at the point where detonation is desired.

The vulnerable area of a concrete or masonry dam for any particular bomb is usually a relatively narrow strip along the upstream face, the width of which depends upon the design of the dam, the elevation of the breach desired, and the height of the water.

11. Railroads and Highways

Rail transport can be reduced by destruction of marshaling yards, bridges, tunnels, rolling stock, and repair facilities.

Rail Lines

500-lb., or 1,000-lb. GP with .025-sec. delay fuze

Rail lines are good targets when they are in areas remote from repair facilities and equipment. Both track displacement and roadbed disturbance can seriously inconvenience the enemy. Craters should be made large enough that power-driven equipment must be used to fill them. An important factor is the settling time necessary to completely re-establish the roadbed. Normal train speeds cannot be resumed until the roadbed has settled, a process that may require several months.

Where the objective is short-time effects with minimum damage to the roadbed, use 100-pound general-purpose bombs with .01-second delay fuze.

Marshaling Yards

100-lb. GP with .025-sec. delay fuze

A marshaling yard presents a target with many vulnerable points. It contains the necessary arrangement of tracks for sorting and making up freight trains, often with intricate electrical switch controls. There are also mains that supply water for engines, telephone and telegraph wires of the railway system (often underground), and rolling stock. A cratering bomb, which provides both earth shock to underground facilities and blast against objects on and above the surface, is desirable.

The 100-pound general-purpose bomb with .01-second delay is the first choice for causing damage to rolling stock and for track cutting.

Shops and Repair Facilities. Use the bombs recommended for attacks against structures.

Highways. The most effective bomb is the one that will produce the crater with the largest diameter per unit of bomb weight. Information is available in various tables, such as those in TM 9-1907. The bombs selected should be fuzed to produce a crater with the maximum diameter; a .025-second delay fuze has been found to be the best.

12. Bridges

Because bridges vary greatly in size, type, and vulnerability, each bridge requires individual analysis as a target. In determining the fuzing to be employed, it is convenient to divide bridges (excluding suspension bridges) into two major categories: bridges primarily of structural steel with the spans supported by masonry or concrete piers, and bridges primarily of concrete or masonry construction with roadbed supported by solid arches from pier to pier.

Steel Bridges. For bridges of average size and primarily of structural steel construction (particularly railroad bridges of single- or double-track capacity), use a 500-pound general-purpose bomb with nondelay tail fuze. To drop a span, a nondelay or a very short-delay tail fuze is recommended to obtain detonation within or close to the bridge member. Nondelay is preferred to instantaneous because it allows the bomb to travel a short distance after impact, thus allowing the center of the charge to penetrate the bridge member. The tail fuze also has the advantage of directing the bomb fragments toward the structural member rather than away from it. Hence, near misses which strike the deck produce more damage if the bomb has a tail fuze. To destroy the decking on bridges of this type, a short-delay nose fuze is preferable because the detonation wave is projected to the rear of the bomb and blows off the decking from underneath. Large bridges of heavy construction require large general-purpose bombs, the size depending on construction details.

Concrete Bridges. For bridges of concrete or masonry-arch construction designed for highway lanes or a double-tracked railroad, use a 1,000-pound general-purpose bomb with a .025- or .01-second delay tail fuze.

Delayed fuzing is necessary to allow the bomb to penetrate the structure before detonation takes place. Otherwise damage will not result. The size and construction of the bridge must be considered, as large bridges naturally require larger bombs.

13. Tunnels

Tunnels are grouped into two categories according to vulnerability: tunnels which pass through rock strong enough to require no lining, and tunnels which require a lining of some type.

Unlined Tunnel. In order to strike the largest vulnerable area of an unlined tunnel, it is desirable to fuze the bomb to penetrate to about the level of the tunnel before detonation. Unconsolidated overburden and weak rock make the entrances the most vulnerable points of an unlined tunnel.

Lined Tunnel. Lined tunnels are better targets than unlined tunnels because they can be made to cave in more easily. The direct shock from a bomb destroys the natural earth arch that helps support the load. The sudden increase in load collapses the tunnel at the point of impact. Induced landslides may also effectively block a tunnel for a limited period.

14. Cities

Planning for an attack against a city requires extensive and detailed analysis of targets and a complete understanding of the objective. This analysis should be made in the following order:

1. Zoning (based on occupancy, usage, type of facility).
2. Density analysis (this establishes three subzones of different density).
3. Structural analysis.
4. Fire division analysis (aerial photos and fire insurance maps).
5. Weapons selection (vulnerability to various types of bombs, such as high-explosive, incendiary, and atomic).

15. Airdromes

The objective of an attack on an airdrome may be to damage aircraft, to crater runways, or to destroy facilities.

Aircraft Parked Outside Shelters

Minimum and low-level attack: 23-lb. parafrag with instantaneous fuze, or napalm

Medium-altitude attack: 20-lb., 90-lb. frag. with instantaneous fuze

High-altitude attack: 90-lb. frag. with instantaneous fuze

Aircraft in Light Dispersal Shelters

100-lb. GP with .01-sec. delay nose fuze and non-delay tail fuze

Runways and Airfields. Where temporary immobilizing effects are desired, use a 100-pound general-purpose bomb fuze to produce a good-sized crater.

Where persistent effects are desired, use a 500-pound or 1,000-pound general-purpose bomb with a .025-second delay fuze. The object is to produce craters so large that heavy machinery must be used to fill them, and a long time will be required for the complete settling of the fill.

Facilities

For destruction: 4,000-lb. LC with instantaneous or air-burst fuze

For building damage only: 500-lb. GP with .01-sec. delay tail fuze

For damaging thin roofs: nondelay tail fuze

16. Ground Troops and Equipment

In selecting the weapons to be used against enemy troops and equipment in the field, you must consider friendly forces nearby.

For troops in the open, use 20-pound fragmentation bombs and napalm or the "Lazy Dog" weapon. Lazy Dog consists of thousands of small-finned projectiles dropped from a fighter or bomber.

For troops in foxholes or trenches, use small general-purpose or large fragmentation bombs with proximity-type fuze and napalm, or Lazy Dog.

For guns in open emplacement, use delay-fuzed bombs for earth shock and cratering, instantaneously fuzed bombs for blast and fragmentation effect, and napalm.

For general-purpose vehicles, with low-level attack, use a 23-pound parafrag bomb; with medium-level and high-level attack, use large fragmentation bombs, small general-purpose bombs with tail fuzed for instantaneous or proximity burst, or napalm.

For armored vehicles, use 500- or 1,000-pound general-purpose bombs with .01- and .025-second delay fuze, respectively. The larger bomb and longer delayed fuzing may be more desirable against such targets as tanks. For this type target, either moving or stationary, napalm appears to be most effective. Normally rockets (see Chapter 2) are the weapons of first choice because of their increased accuracy.

For guns in revetted emplacements, use 100-pound general-purpose bombs with .01-second delay or instantaneous fuze. As direct hits are usually necessary to cause damage to such targets, the attack might better be designed to harass or hinder the operations of personnel or destroy auxiliary equipment. Napalm could also be used effectively against this type of target.

For guns in concrete casemate, use armor-piercing bombs, semi-armor-piercing bombs, or napalm, depending on the nature of the target.

17. Ships and Submarines

Vessels of all classes are vulnerable to sinking by bombs, but this vulnerability varies widely with type and size. In general, sinking can be achieved only by damage below the water line; near misses will damage effectively only if close to the hull at the water line. To penetrate the heavily armored decks of battleships and aircraft carriers, bombs must be dropped from sufficiently high altitudes to insure maximum striking velocity. Since heavily defended warships are difficult to attack, it is advisable to first cripple them or neutralize their defenses.

18. Submarine Assembly Yards

Submarine assembly yards are a kind of fabricating factory, since most of the components are shipped in from elsewhere. Such yards usually consist of three areas: the uncompleted vessels on the ways, the shops in which some of the processing of the parts is done, and the warehouses in which these parts are stored. In attacks on submarine assembly yards use general-pur-

pose bombs varying from 500 pounds to 1,000 pounds. Select the fuze according to the area to be attacked.

19. Shipyards

Shipyards, like submarine yards, are to some extent fabricating factories, but as targets they present many of the problems of industries using heavy machine tools. No general recommendation can therefore be made as to the bomb and fuze combination to use when attacking any one portion of the yard. As in the case of industries using heavy machine tools, no generalized bomb and fuze selection should be made.

20. Submarine Pens

This class of target presents problems comparable to heavy gun emplacements, except that the area is larger. Only the largest of bombs with armor-piercing heads should be used. Bombs weighing 25,000 pounds, with special heads and explosives, have been used against submarine pens to breach the reinforced concrete tops, approximately 14 feet thick. The bomb should be fuzed to explode after it has attained maximum penetration.

NEW DEVELOPMENTS

Bombs of the type used during World War II are not entirely satisfactory for modern high-speed and high-altitude aircraft. The principal difficulty lies in the fin, a sheet metal box, which has long been standard equipment on our bombs. When the bomb is carried externally at a high speed or dropped from a high altitude, the high-speed air load causes the box fin to vibrate and flutter and often to break away from the bomb. This results in tumbling of the bomb and, consequently, a serious bombing error. Another disadvantage of this type bomb is the blunt nose. When carried externally, the blunt nose contributes to a high over-all drag on the aircraft and a loss in speed.

To overcome these difficulties two programs have been set up. As an interim measure, a stronger and more streamlined

fin has been designed and tested. This cone-and-blade fin, as it is termed, is for use on the general-purpose bombs of 100-, 250-, 500-, and 2,000-pound weight. As a long-range measure, bombs are being redesigned. The new bombs can be accurately dropped at high speeds and high altitudes.

21. Cone-and-Blade Fin

The new cone-and-blade fin allows for a gain in accuracy, but not without penalty of a reduced bomb load. You will note from Fig. 1 that the new T-127 cone-and-blade

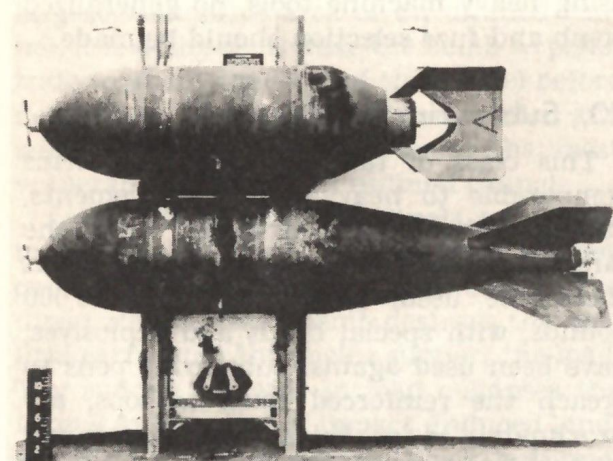


Fig. 1. The 500-pound general-purpose bomb shown with the old type box fin (top) and with the new T-127 cone-and-blade fin (bottom).

fin fitted to the 500-pound general-purpose bomb increases the over-all length of the bomb. Ten inches have been added to the tail of the bomb. It is possible that some of our aircraft will be modified to carry a maximum load of bombs equipped with the new fins, but it is more likely that the bomb bays instead will be modified to carry the new series of bombs.

22. New Bombs

The cone-and-blade fin, while helping to make our present stockpile of bombs more accurate and useful, does not entirely overcome deficiencies. The blunt nose is still not compatible with high-speed flight, and bombs develop excessive instability upon contact with the high-speed slipstream. Because we had many types of bombs whose suitability could be questioned, the Army

Ordnance Corps contracted with Lehigh University to study available data and recommend the sizes of bombs which the Air Force needs to accomplish its mission. The data included voluminous information accumulated from the strategic bombing surveys which were made after World War II.

From these studies it was possible to determine the tonnages, types of bombs, and types of fuzing which had resulted in the greatest destruction of the target per ton of bombs dropped. As a result of these studies, it was decided that 750-pound, 3,000-pound, and 10,000-pound bombs could replace all the other conventional types of bombs. But, since a fighter aircraft can carry 1,000 pounds on each pylon and since the requirement for low drag is more critical in the fighter, a special 1,000-pound bomb was built for this purpose. It was also recognized that the Air Force requires miscellaneous small munitions, such as the 4-pound incendiary bombs, the 20-pound fragmentation bombs, and various chemical bombs. These small munitions are clustered in a container of the same shape as the 750-pound bomb. The new bombs are as follows:

1. A large bomb weighing 10,000 pounds, which contains 77 percent high explosive, to be VT (proximity) fuze for air burst. Since this bomb is the largest and yields the greatest blast area per ton of explosives, it is used for a blast of long duration.

2. An intermediate bomb weighing 3,000 pounds, which contains 67 percent high explosive. This bomb will be instantaneous or proximity fuze. To insure efficient stowage in bomb bays, it will be the same length as the large bomb and one-half its diameter. Thus, four intermediate bombs can be carried in the space occupied by one large bomb.

3. A small bomb which weighs 750 pounds and contains 50 percent high explosive. This bomb may be provided with an instantaneous, delay, or proximity fuze. The small bomb is approximately one-half the length of the large bomb and one-third its diameter. Eighteen of the small bombs can be stowed in a bomb bay that accommodates one large bomb. Because of its shape, the

case used for the small bomb can be adapted to carry a cluster of miscellaneous small munitions.

4. A low-drag bomb, with a weight of 1,000 pounds, to be carried externally on fighters.

The disadvantages of the new bombs are similar to those of the old bombs equipped with the cone-and-blade fin. The same loss of tonnage (about half) is suffered when the new bombs are stowed in bomb bays designed for the old bombs. The newer types of bombardment aircraft, however, are designed to carry the maximum load of the new bombs with a less critical loss in tonnage.

23. Electric Fuze

A new electric fuze will soon be available to the Air Force. Designed to replace about 28 standard fuzes, this is an "all-ways" fuze—one that functions regardless of how the bomb strikes the target. It is designed so that the desired arming and impact delays are selected by various RC (resistance-capacitance) circuits.

The selection can be made from the bombardier's control panel at any time until the instant the bomb is actually released. The bombardier can vary the impact setting from instantaneous to an 11-second delay by simply turning a dial on the control panel. This ability to set the impact delay in flight is important. If for some reason the primary target cannot be attacked and a secondary target, or target of opportunity, has to be selected, the bombardier can turn the dial and reset the impact delay in the fuzes in order to gain maximum results on the secondary target.

Another important advantage of the new electric fuze is that the bombardier can also set the arming delay. The dial for this setting has a range from 2 to 20 seconds. By setting the arming delay at the time of release, bombardiers can adjust it to the true air speed. This system is an improvement over the old arming vane-type fuze, which could become armed before the aircraft was out of lethal range of the bomb. Accelerated arming resulted when the high

wind speeds at release turned the arming vane too rapidly.

While the new electric fuze is being carried in the aircraft, there is a mechanical device which blocks any signals to the fuze. The signal from the bombardier's control panel that arms the fuze reaches it through an electrical connection on the side of the bomb. The connection contains a small cable device which does not allow the signal to be given until the bomb has fallen at least eight inches from its station.

These advantages are gained from the electrical fuze:

1. Standardization. One fuze replaces most contact fuzes now in use, thus simplifying manufacturing and logistics.
2. Flexibility. Modifications of the basic system may be made at a later date as the need arises.
3. Tactical freedom. The bomb is controlled from the bombardier's panel, and its impact and arming delay can easily be changed until the instant of release.
4. Reliability. The simple electrical circuit is expected to be more reliable than the more complex mechanical systems.
5. Safety. The fuze is inert until charged, and no charge is supplied until after the bomb has been falling for some seconds.

24. Comparison of Old and New Bombs

The new bombs reduce the tonnage capacity of present aircraft. For example, the B-36 can carry 132 of the 500-pound bombs of the old box-fin type but only 44 of the 750-pound bombs of the new series. This amounts to a reduction of one-half of its tonnage capacity. On the surface this disadvantage appears to be very serious, but let us examine it more closely.

During World War II it was often reported that a certain air force dropped so many tons of bombs on the target. No statement was made about how many of these bombs hit the target. Of course, the

object of a bombing mission is not to drop tons of bombs over a target but to hit the target.

Since the high-explosive weapons appear to have been relegated to use on small-area targets, let us compare the effectiveness of a B-36 plane load of the old 500-pound bombs with a B-36 plane load of the new 750-pound bombs. For a target, let us select an area 1,000 feet in diameter. Under the same conditions, which plane load will be more effective—that is, which plane load will put the greater number of tons within this 1,000-foot circle? If the B-36 is flying at 30,000 feet, the predicted error with the old 500-pound bombs would be 37 mils. (A mil is a unit of error in a falling bomb—one foot for each 1,000 feet of altitude above the target.) A 37-mil error at 30,000 feet would place the bomb 1,110 feet away from the target. Now let us add a constant of a 15-mil bombing error for all other reasons. Using mathematical probability, we determine that only 28 of the 132 bombs dropped can be expected to fall within this circle. In other words, we have hit the target with 7 tons of bombs. The other 104 bombs will fall out of the 1,000-foot circle in a normal distribution pattern.

Under exactly the same conditions, let us now determine how many of the 750-pound bombs of the new series will fall within this 1,000-foot circle. The predicted error at an altitude of 30,000 feet is 3 mils. Now, adding the constant 15-mil error for all other reasons and using the same calculations, we find that 25 of the 44 bombs dropped will hit within this 1,000-foot circle. In other words, we have placed 9.4 tons of bombs on the target. Even with the reduced tonnage capacity, the new bombs, per plane load, are more effective.

In January 1952 the Air Force began a study to see if there was some way of increasing the tonnage capacity of present aircraft for carrying the new bombs. Beginning with the B-52, future aircraft will be designed to carry a maximum load of the

new bombs. Modification of present aircraft is already underway. The B-47 is now being modified to carry the new bombs.

As the result of an analysis of certain potential targets, a semi-armor-piercing bomb may be included in the new series. This bomb will be of the 3,000-pound size, but will weigh between 5,000 and 6,000 pounds. Also, because it has been determined that small bombs are most effective against targets such as runways, where a good tonnage distribution is desired, there is being developed a small bomb of the 100- to 250-pound class that may be included in the new series.

SUMMARY

THE FACT that the Air Force has put time, money, and effort into developing bombs using conventional explosives indicates that, far from being obsolete, these bombs can be adapted to many uses and remain an important part of the Air Force arsenal. This chapter has described the basic types of high-explosive and fragmentation bombs. It listed the type of bomb and the fuze setting best suited to each kind of target to obtain maximum results from minimum effort. Strategic bombing surveys of World War II revealed that even direct hits caused little or no damage if the bombs were not properly fuzed. Just as an instantaneous-fuze bomb would be ineffective against a submarine pen, so might a deep-penetrating, high-explosive bomb be wasted on enemy troop concentrations.

The key to the timing of a bomb's explosion is its fuze. New developments in Air Force bombs include a variable electric fuze that can be set at the last minute by the bombardier. On the whole, this fuze is safer, more easily operated, and much more efficient than the 28 different kinds of mechanical fuzes it replaces.

But fuzing is not the only problem in bomb design. One weakness of World War II type bombs is their tendency to tumble and fall wide of the mark because of their blunt noses and box-type fins. As an interim measure, the Air Force is renovating its

REVIEW QUESTIONS

present stockpile of World War II bombs by substituting a new, longer type of cone-and-blade fin for the older type fin. Besides revamping old bombs, the Air Force has developed four new bombs: a 750-pound bomb, a 3,000-pound bomb, a 10,000-pound bomb for internal carriage, and a 1,000-pound bomb for external carriage. In the future there will be a semi-armor-piercing bomb weighing between 5,000 and 6,000 pounds (of the same size as the 3,000-pound bomb) and a small bomb, between 100 and 250 pounds. All of these bombs are more streamlined than previous models. Their dimensions are fixed in definite ratios to each other so that, for example, four 3,000-pound bombs occupy the same space in a bomb bay as one 10,000-pound bomb. The new bombs simplify logistics and make greater accuracy possible.

1. What is the charge-weight ratio of a 4,000-pound light-case bomb? A 4,000-pound general-purpose bomb? One of the new 3,000-pound general-purpose bombs?
2. Why would a high-explosive light-case bomb be ineffective against a 20-story steel-frame office building?
3. In a steel mill, which type of installation presents the best target?
4. Does the new cone-and-blade fin overcome all the deficiencies of the older type bomb?
5. If the bombardier can set the new type electric fuze by turning a dial on his control panel, what prevents him from accidentally blowing up the aircraft in flight?

Aircraft Weapons

THE DESIGN of a combat aircraft, bomber or fighter, includes the design of the armament which is best suited to the mission of the aircraft. Inadequate armament imposes an unnecessary handicap on the pilot and crew and reduces the effectiveness of the airplane. For this reason research and development of air armament must be undertaken vigorously with the most competent personnel available and with adequate funds. Failure in this important work would mean failure in actual combat.

The purpose of this chapter is to familiarize you with air-to-air combat weapons and to consider some of the important factors in armament selection. The chapter is divided into three parts: (1) basic factors in evaluating aircraft weapons and accessory equipment, (2) the application of these factors to bombers, and (3) the application of these factors to fighters.

25. Evaluation of Air Weapons

Numerous projectile-launching mechanisms, guns, cannons, and rockets in the developmental stage are being evaluated to determine their effectiveness as aircraft weapons. Effectiveness, as we use it here, is a precise word. Its meaning is expressed in the following formula:

$$E = \frac{HRD}{W}$$

Effectiveness equals hits per round times rounds per engagement times destructiveness per hit divided by the weight.

For the purpose of this discussion, let us consider next the factors that contribute to the effectiveness of the weapons system. You should bear in mind that each factor is interrelated with, and influenced by, all the others.

Cyclic Rate. The cyclic rate of the weapon is the number of shots per unit of time. Some guns have a relatively high rate of fire, as illustrated by the present caliber-.50 aircraft guns (1,200-1,500 rounds per minute). Others, such as the 75-mm. gun which was installed in the B-25, fire very slowly (3 to 10 r.p.m.). Guns now being tested fire at rates of 900 to 6,000 r.p.m. The higher rates of fire are desirable because, other factors being equal, the greater the bullet density of a given air space, the more probability there is of a hit on the target. Engagements in aerial combat are extremely short, and effective firing time in a normal pass is momentary.

Velocity. The velocity of a projectile depends not only upon the driving force of the propellant but upon the shape of the round. It is obvious that a much greater force is required to push a flat-faced projectile than a tapered one. Resistance to the air mass is accounted for by a factor called the *ballistic coefficient*. At a fixed range (distance to the target), velocity and the ballistic coefficient determine the time of flight.

It is desirable to reduce to a minimum the time of flight in order to reduce the amount of drop produced by gravity and windage. The influence of gravity causes the projectile to drop vertically during its flight. The correction for this drop is called *ballistic lead*. The windage effect is more complex and is a far more important factor for correction. The relative wind causes the trajectory of the projectile to be curved. This curve must be compensated for in order to obtain a hit on the target. Furthermore, if the projectile is fired directly into the wind, its velocity and effective range are

reduced. If the projectile is fired in the same direction as the relative wind, the velocities are added, increasing both the velocity of the projectile and its effective range.

Effective Range. This factor varies with the weapon. World War II guns had an effective range of about 400 yards, which was generally adequate at that time. However, the increased speeds and high altitudes at which aircraft fly have made necessary an extension in effective range. To have time for finding the target and locking onto it and for firing enough rounds to insure a reasonable probability of hits, it is necessary to begin firing at ranges in excess of 1,500 yards. Since radar is more accurate in making measurements for range than for small angles, it is difficult to develop sighting mechanisms that can distinguish small angular variations at ranges over 1,500 yards. There are two probable results of this limitation: (1) sighting mechanisms will be constructed to this 1,500-yard limitation, and (2) target-seeking missiles will be developed to increase the range of air-to-air weapons beyond 1,500 yards.

Damage Potential. Closely allied to effective range and firing time is the damage potential. The size of the projectile, as well as its filling (high-explosive, incendiary, armor-piercing core, or combinations of these), bears a direct relation to the weapon's kill potential. The probability of causing a serious fire in the target is reduced at altitudes above 45,000 feet because of the atmosphere's reduced oxygen content. Under such a condition, a high-explosive round would be considerably more effective than an incendiary round.

Weight. The weight of the weapon, including ammunition, is an important factor from the standpoint of design. It is obviously unsound to install a weapon heavy enough to impair the efficiency of the aircraft. It should be remembered that the gun barrel, chamber, and attendant equipment are so much dead weight. It is the missile that accomplishes the destruction. Aircraft range, rate of climb, speed, and maneuverability are directly affected by the weight of installed weapons. For this rea-

son, armament weight must be reduced as much as possible without sacrificing the kill potential.

Horsepower. The efficiency of a weapon may be gauged by the horsepower per pound of gun weight and the time required for the gun to shoot its own weight of ammunition. The ratio of horsepower to weapon weight should be high, and the time required for the gun to shoot its own weight of ammunition should be low. The term *horsepower* refers to the built-in ability of the weapon to deliver the maximum foot-pounds of energy in the form of projectiles per unit of time. This horsepower varies with the muzzle energy of the ammunition used.

Other Considerations. The factors of mechanical reliability and ease of installation, loading, and maintenance must be analyzed in evaluating weapons. The dispersion of the projectile is also a factor to be considered, especially with the development of air-to-air rockets. Present techniques for firing a projectile through a rigid tube are more accurate than the former unguided launchings.

26. Bombers in Air-to-Air Combat

An important part of carrying out a bomber mission is reaching the target and returning to a friendly base. The armament selected should help the bomber protect itself en route to and from the target. Factors such as speed and altitude also have a bearing upon the problem of bomber protection; however, we shall limit our discussion to the armament factor. The bomber, because of its characteristic size and design, has certain advantages and disadvantages in self-preservation.

Advantages. As the bomber can carry a complicated and complete fire control system, it is difficult for an attacking fighter to strike without becoming vulnerable to the bomber armament. Relative speeds, altitude, search equipment, and fighter armament design limit the attacking aircraft to either a head-on or a stern attack. Whereas the head-on attack is possible, it is not the better of the two. With the bomber and fighter approaching each other at approxi-

mately 1,000 m.p.h. (1,467 feet per second), and with effective range of aircraft guns limited to 1,200 feet, it is obvious that time for firing is extremely limited. Therefore, the attacking fighter normally follows an exact or modified pursuit curve. This will invariably bring the fighter into the bomber's stern. The problem of the bomber then becomes one of sighting on the fighter with an accurate weapon of sufficient size and muzzle velocity. In a stern attack, the factor of relative wind becomes important because the bomber is firing downwind, whereas the attacking fighter must fire upwind at a decreased range. The T-121 fires a 30-mm. projectile with a low-muzzle velocity approximating 1,200 feet per second. Its value as a weapon is increased by the added velocity which the relative wind gives it. Each 30-mm. projectile is sufficiently large to cause major damage, and a cyclic rate as low as 900 r.p.m. is acceptable. This gun is similar in operation to the T-130 gun, which is described later in this chapter.

Disadvantages. The bomber has the disadvantage of being a large target with many vulnerable components. Also it can engage in relatively little evasive action and, once committed to the operation, must carry it through.

In selecting armament, it is important to realize that the attacking fighter will press an attack vigorously. This means then that the destructive force of the bomber armament must be sufficient to destroy, rather than cripple, the attacking fighter. A critically damaged fighter might still be capable of damaging the bomber and forcing it to abort.

27. Armament for Fighters

Fighter-type aircraft have the following missions: to prevent the enemy bomber from accomplishing its mission, to destroy or fend off enemy fighters that threaten the friendly bomber, and to give direct support to attacks by ground troops or surface vessels.

The factors to be considered in the selection of aircraft armament are not the same for fighters as for bombers. For in-

stance, modern fighters have only limited space for weapons and equipment for search and fire control.

Air-to-Air Armament. As we have pointed out, fighter aircraft normally attack a bomber from a stern position, using a modified pursuit curve to get into a firing position. This is true because the high wing loading of the modern jet fighter (70 to 80 pounds per square inch) limits it to a turn of three G's or less. Head-on attacks can be made, but they allow such limited time for aiming and firing that the probability of hits is extremely low.

When head-on attacks are made, high cyclic rates or the assurance of a very high order of accuracy is mandatory, since time for firing is very short. The selection of ammunition is also an important consideration because each hit must cause maximum damage. The velocity of the projectile is more important in fighter armament than in bomber armament because of the relative wind.

It is quite possible that, in a stern attack, with high target speed and moderate projectile velocity (1,000 feet per second), the projectile velocity would drop below the target velocity. The projectile would never reach the target.

The 2.75-inch rocket is now being used to increase the effective range and, in addition, to provide a higher single-shot kill probability. The problems of sighting equipment and rocket dispersion have been solved satisfactorily.

The relative importance of these factors will probably change when flexible-turreted fighters come into use. These fighters are not limited to following a pursuit curve when making an attack.

Air-to-Ground Armament. In the selection of armament for fighters engaged in tactical air support of surface forces, the same factors as those just described must be considered, especially where air superiority is concerned.

Other factors enter into the selection of armament for aircraft that are used in isolating the battlefield and in supporting ground forces. Bullet density becomes im-

portant. During the interval in which the aircraft fires a five-second burst, much ground is covered. Too few missiles may strike an area, or the missiles may be too widely dispersed to be effective. For attacking armored vehicles, gun emplacements, or even ordinary concrete or brick structures, missiles must have considerable penetrating power. The type of armament to be used will depend upon the type of mission to be flown, since air-to-air armament may be totally unsuited for air-to-ground combat.

28. New Aircraft Gun

Now that we have considered some of the problems of aircraft armament, let us briefly examine some of the weapons developed by the Air Force in recent years.

An important new development in aircraft guns is a combination gun. By changing the drum assembly, the barrel, and one guide insert in the top of the feeder, this gun can be used either as a 20-mm. automatic (T-160) or as a 15.2-mm. automatic (T-130). Also, by changing and relocating certain parts, the gun may be converted from a left-hand to a right-hand feed.

The T-130-160 is a gas-operated, belt-fed, electrically-fired weapon. Packing a cannon-like wallop, this fast-firing heavy machine gun borrows at least one mechanical principle from the old-fashioned six-shooter. That is a revolving drum containing five-cartridge chambers parallel to its axis of rotation and mounted upon the shaft in the drum cradle. Like an ordinary revolver, this mechanism follows the principle of having a rotating cartridge chamber become the firing chamber when it lines up with the barrel. But there the resemblance ends. In this oversized "revolver," belted ammunition rolls into a feeder behind the drum and is fed from the belt into the rotating chambers.

In a little more detail this is what happens to a round of ammunition as it comes off the belt into the receiver of the gun: Assuming that the round is being fed from the right and the drum is rotating counterclockwise, the cycle begins at eleven o'clock. (These "clock" positions, of course, are only

approximate; they are supposed to represent equal fifths of the circle.) At eleven o'clock on the drum, the incoming shell is rammed out of its belt clip halfway into a chamber of the drum, which carries it down to nine o'clock. There another rammer pushes it all the way into the chamber. These rammers work fast, but they must at the same time be safe, as the shell has no percussion cap and is fired electrically. Down at six o'clock, the shell is aligned with the barrel, and an electric contact fires it. The empty shell then moves up to four o'clock, where an extractor throws it out. The chamber in the drum is empty for a fraction of a second at one o'clock, before it begins a new loading cycle.

The gun has other interesting features. The barrel is housed in a bearing attached to the front end of the receiver and is retained by interrupted screw threads and a latch in the front end of the drum cradle. When assembled with the receiver, the cylindrical front end of the drum cradle engages the bearing in the receiver. The barrel, drum, drum cradle, and parts attached to the drum cradle constitute the recoiling parts of the weapon. Recoil and counterrecoil forces are limited by two sets of ring spring assemblies housed in the receiver. During firing, a chamber in the drum is held in alignment with the barrel. The drum is then indexed one-fifth revolution to bring the adjacent chamber into alignment with the barrel by means of five rollers on the periphery of the drum. These rollers engage a cam track in the bottom of the receiver.

The total weight of the gun is 180 pounds; the over-all length, 72 inches; the over-all width, 8¼ inches; and the over-all height, 8¼ inches.

There are two principal advantages of the T-130-160 gun: (1) By ramming cartridges in two short motions, the reciprocating parts travel only half the normal distance. This results in an increased rate of fire. (2) The caliber may be changed in the field by changing the barrel, the drum assembly, and parts of the feeder.

The gun combines high-muzzle velocity, fast cyclic rate, and great damage potential.

It is apparent that this gun works out a compromise solution for a basic problem of World War II aircraft guns. Essentially this was the problem: Heavier projectiles were needed but, with a weapon of a heavier caliber, the rate of fire was slower, and the number of rounds of ammunition that could be carried in the aircraft was reduced. Also, the size and weight of the gun itself had to be considered. In the 20-mm. and 15.2-mm. projectiles we seem to have achieved the best sizes. They are an effective compromise between the greater carrying capacity of lighter ammunition and the greater destructiveness per shot of heavier ammunition. The gun itself provides this heavier blow without excess weight and with a high rate of fire formerly possible only in lighter caliber weapons.

29. Aircraft Rockets

Aircraft rockets add tremendous punch to fighter armament. Armed with a load of rockets, a fighter aircraft is a potent weapon that combines speed and maneuverability with the firepower of an artillery piece. The result is "flying artillery" that can quickly and effectively strike at distant targets with high-velocity, large-caliber projectiles.

Heretofore, because of severe recoil and lack of compact guns and gun mounts, the size of the projectile that could be conveniently fired from fighter aircraft was limited to 20 mm.—about eight-tenths of an inch in diameter. Yet these same fighters, equipped with simple, lightweight launchers, could carry and fire rocket projectiles with diameters of five inches and more.

This increase in firepower, without the handicaps of cumbersome firing devices, is an important advantage stemming from the recoilless take-off of the rocket. When a rocket is launched, its motor produces a thrust that acts only on the projectile. The aircraft experiences no recoil. The size of the rocket is governed mainly by convenience in carrying it. Any size rocket can be carried that does not seriously limit the performance of the plane.

High-Velocity Aircraft Rocket (HVAR). The 5-inch HVAR (Fig. 2) is a fin-stabilized

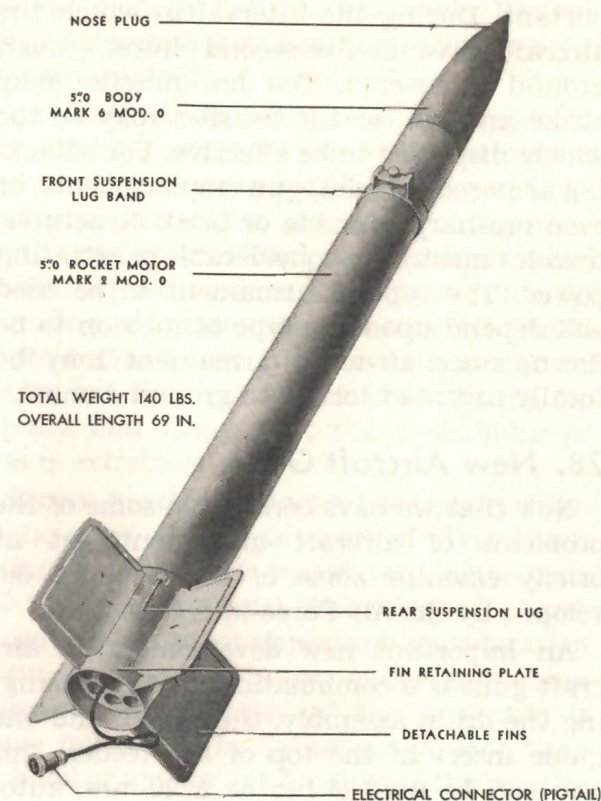


Fig. 2. The 5-inch HVAR.

rocket designed to be fired from high-speed aircraft at ground targets, such as armored vehicles, locomotives, and gun emplacements. The rocket, which is fired from an externally mounted launcher, consists of a high-explosive (HE) head with both nose fuze and base fuze; a motor tube, containing a 24-pound grain of nitroglycerin-nitrocellulose and an electrically activated igniter assembly; four fixed fins; and an eight-unit nozzle assembly. A ninth nozzle, at the center of the assembly, which is ordinarily sealed with a blowout disk, provides an additional exit for the gases in case the motor pressure should exceed 2,400 pounds per square inch. The allowable service temperature of the motor is thus extended to approximately 120°F.

Two types of the 5-inch HVAR are in use. They are identical except for the method used to suspend them from the launcher. The Navy type, used with post-type launchers, is suspended by a pair of bands encircling the middle and rear of the motor tube. The second type, a modification of the

Navy type, is used with the flush-mount launcher. The rocket is suspended at three points: at a lug band encircling the middle of the motor tube and at the two upper rocket fins, whose sockets engage the igniter plugs in the aft launcher posts. The modification is accomplished by using the lug band, fin assembly, igniter wire assembly, and igniter plug contained in the M34 rocket modification kit.

The 5-inch Mark 6 rocket head is loaded with approximately eight pounds of high explosive. A plaster-filled head, containing a dummy fuze, is also available for practice firing. The 5-inch antitank aircraft rocket (ATAR) having the shaped-charge Mark 25 head, has been developed for heavy armor penetration (17 to 18 inches). The explosive heads are assembled with the nose fuze Mark 149 and the base fuze Mark 159, or, in later rockets, with the base fuze Mark 164. To obtain fragmentation and blast effects over a larger area, the rocket head can be detonated above the ground by means of the proximity fuze, M403.

The nose fuze is of the propeller-arming, impact-detonated type that, by means of cockpit selector switches, can be set either to function immediately on impact ("super-quick") or to remain inert ("safe"). When armed, the fuze will detonate the head immediately upon striking any object or a water surface. Despite the fact that the rocket head explodes on impact, a round carrying a high-explosive head and a nose fuze Mark 149 can penetrate approximately one foot into a six-foot semireinforced concrete wall.

If the nose fuze is fired "safe," the rocket is detonated by the action of the pressure-arming base fuze. The base fuze Mark 159, like its successor, the Mark 164, is located in a cavity in the base of the rocket head and is armed by pressure exerted by the gases in the adjoining motor tube. The rocket must never be fired unless the base fuze is firmly in place; otherwise, the propellant gases will contact the explosive filler and detonate the head during launching.

To allow the rocket head to penetrate farther into the target before exploding,

the base fuzes used with the 5-inch HVAR have an arming distance of approximately 600 feet at 70° F. and are designed to function .015 second after impact. A round with a high-explosive head and the base fuze Mark 159 can usually penetrate a three-foot reinforced concrete wall.

The 5-inch HVAR, completely assembled, is 69 inches long and weighs 140 pounds. Performance data for the rocket, when launched at 350 m.p.h., are as follows:

Burning time (70° F.)	0.88 sec.
Burning distance (relative to ground)	1,100 ft.
Velocity at burnout (relative to ground)	1,800 ft. per sec.
Dispersion (standard deviation)	3 mils
Service temperature limits	—20° F. to 120° F.

The 5-inch ATAR is 83 inches long, but is similar in performance to the 5-inch HVAR, which is 69 inches long.

Folding-Fin Aircraft Rocket (FFAR). The 2.75-inch folding-fin aircraft rocket (Fig. 3) is intended for either air-to-air or air-to-ground firing from high-speed aircraft. As an air-to-air weapon, the rocket carries a 1.4-pound high-explosive blast head with a point-detonating fuze. For air-to-ground attack, the rocket is assembled with a .7-pound shaped charge (designated HEAT, for "high explosive antitank"). The shaped charge is designed to detonate so that most of its force is expended in one direction. It is particularly effective against tanks and other types of armored vehicles.

The assembled rocket consists of an explosive head, an aluminum motor tube containing an extruded grain of nitroglycerin-nitrocellulose and electrically activated igniter, and a combined fin-and-nozzle assembly consisting of four nozzles and four folding fins. The use of a lightweight aluminum motor tube is possible because the propellant grain is designed to burn at relatively low pressure and temperature.

The rocket is loaded in a tube-type launcher, with the four fins folded inward behind the nozzles. After the rocket emerges from the tube, the fins are forced out and

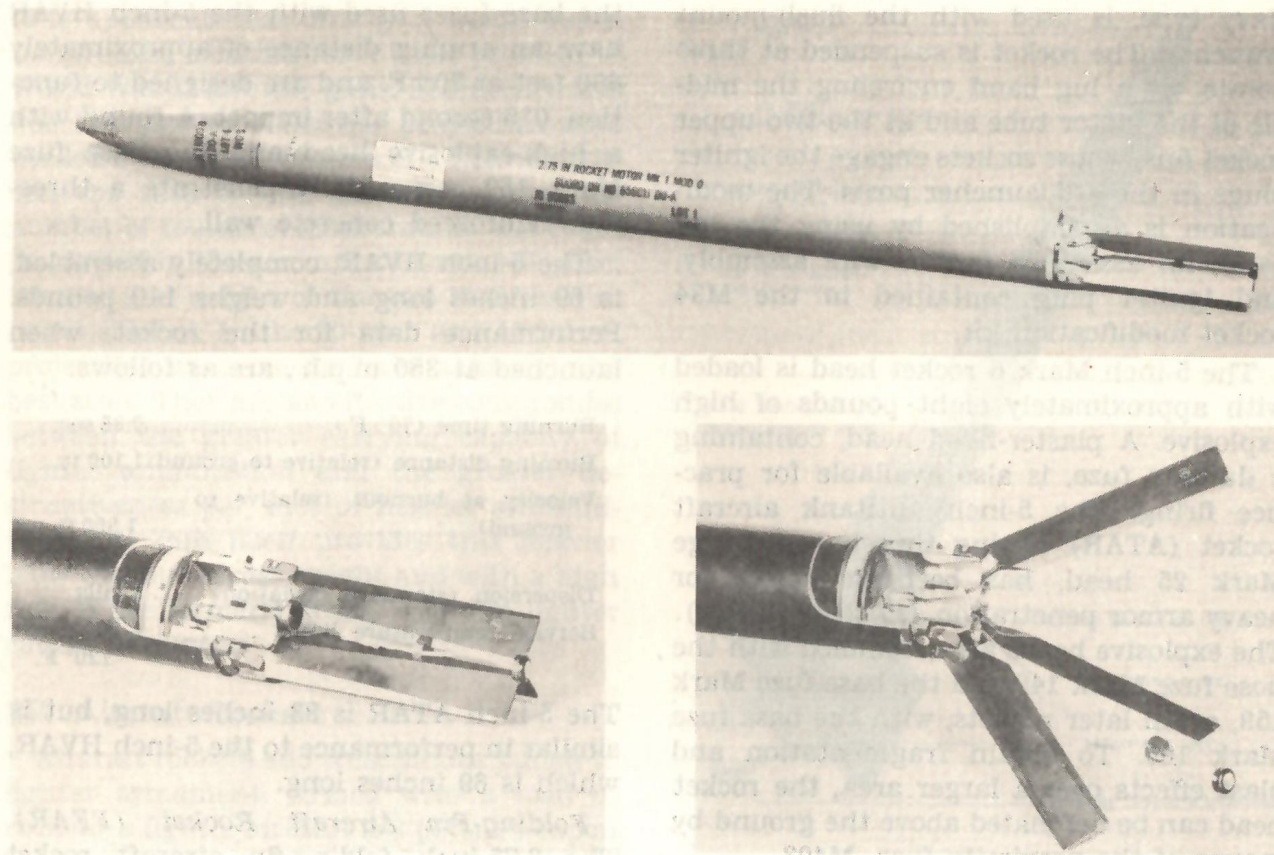


Fig. 3. The 2.75-inch folding-fin aircraft rocket, with details of folding-fin design.

locked in an extended position, stabilizing the rocket in flight.

Completely assembled, the 2.75-inch folding-fin aircraft rocket weighs 18.5 pounds and is 48 inches long. Performance data for a 440-knot launching speed are as follows:

Burning time (70° F.)	1.8 sec.
Burning distance (70° F.)	1,100 yd.
Velocity at burnout (70° F.)	2,600 ft. per sec.
Dispersion (air firing, standard deviation)	
Low altitude, 440 knots	3.5 mils
35,000 ft., 440 knots	4.5 mils
Service temperature limits	-20° F. to 120° F.

Liquid fuel motors, now being developed for the 2.75-inch folding-fin aircraft rocket, are expected to increase the velocity of the rocket, widen its range of service temperature, and increase its storage life.

SUMMARY

A CAREFUL STUDY shows that all problems of aircraft armament are interrelated and are

concerned with the same objective. The objective is stated simply in terms of hits per round, rounds per engagement, destructiveness per hit, and weight. Using these standards, you can even compare guns with rockets. A rocket rates very high in destructiveness per hit and in the low weight of launching mechanism, as compared with the live weight of the projectile. Guns rate much higher than rockets in rounds per engagement.

Factors contributing to these standards of effectiveness include the cyclic rate of guns (shots per unit time, usually per minute); the velocity of projectiles, determined by both the driving force of the propellant and the shape of the projectile; the effective range, which must be much longer in projectiles fired from modern high-speed aircraft than from the aircraft used in World War II; damage potential, related to high-explosive, armor-piercing, and incendiary projectiles; weight of the weapon and ammunition combined; horsepower of weapon,

varying with the velocity, or muzzle energy, of the ammunition and indicated by the time required for the weapon to shoot its own weight in ammunition; and a number of other considerations, such as mechanical reliability, accuracy, and ease of installation and maintenance.

Along with these factors, the characteristics of the aircraft themselves must be considered. Bombers, for instance, can bristle with armament aimed in all directions so that a fighter will be vulnerable if it attacks; however, bombers make large targets with many vulnerable components and can take only limited evasive action, especially when making a run on the target. Although fighters can take evasive action, they do so under severe strain. Their great speed and the shortness of their engagement time increase the effective range needed and reduce the bullet density. They therefore need weapons that have a high cyclic rate and that fire high-velocity projectiles. However, to attack ground targets effectively, fighters need missiles of greater impact and penetrating power. Since all these needs cannot be resolved in one weapon, fighter armament must depend upon the mission to be flown.

The Air Force has found a weapon of much versatility in its new T-130-160 automatic gun. This gun comes in two calibers (which are made interchangeable by switching barrels and other parts): 15.2-mm. and 20-mm. Its best medium-sized projectiles have high velocity and are a compromise between the higher destructiveness of heavier shells and rockets and the higher cyclic rate and capacity for greater number of rounds provided by lighter ammunition. The gun is six feet in over-all length and weighs only 180 pounds. Its high cyclic rate is made possible by electric firing and a unique gas-operated mechanism that feeds ammunition from a belt into a five-

chamber rotating drum. In principle, the drum is roughly similar to the cylinder of a revolver.

Aircraft rockets add a big punch to fighter armament, turning fighter planes into flying artillery. Recoil forces and weight limit the caliber of guns that can be mounted on a fighter, but the same fighter can carry rockets of 5-inch and greater diameters. An effective weapon against ground targets is the 5-inch HVAR. Its two fuzes, one in the nose and one in the base, allow it to explode on impact or after a .015-second delay. It can also be fuzed for air burst over a large area with either fragmentation or blast effects. Closely related to it is the longer nosed 5-inch ATAR, designed to penetrate heavy armor.

A smaller rocket, adaptable for either air-to-air or air-to-ground firing, is the 2.75-inch FFAR. Carrying capacity for these rockets is increased by folding fins. These fins pop out and lock into position after the rocket has emerged from its tube, stabilizing it in flight. The propellant used is nitroglycerin-nitrocellulose. A liquid-fuel motor now being developed should be an improvement.

REVIEW QUESTIONS

1. Why is a high-muzzle velocity desirable in a projectile?
2. What are some of the armament problems brought about by the high speed of modern jet aircraft?
3. Is a high-muzzle velocity needed in the tail gun of a bomber?
4. Why does the T-130-160 gun have two rammers instead of one?
5. If a 5-inch ATAR rocket is fired to explode on impact, what fuze or fuzes must it carry? Why?

Chemical Warfare

CHEMICAL WARFARE is the military use of incendiaries, smoke, and toxic chemicals. Within each of these three classes there are several substances known as chemical agents, which are used as the filling or active material of the munition. The Air Force commander should understand the agents and munitions for conducting operations with smoke, incendiaries, or toxic chemicals; the application of such agents and munitions; and the defensive measures that can be used against them.

First let us consider two factors which, though unrelated, must be understood before we can discuss chemical warfare. One is *command responsibility*; the other, *micrometeorology*.

Chemical warfare may involve either offensive or defensive operations. Conduct of either is a command responsibility. The responsibility for defense against chemical weapons usually falls to the airdrome or wing commander, but planning for the offensive use of chemical weapons may take place at other command levels.

There are no combat restrictions on the use of smoke or incendiary munitions, and operations using them are conducted in a manner similar to other combat missions. The United States is not a signatory to any treaty forbidding the use of toxic chemicals. They were not used by the Allies during World War II, because President Roosevelt and Prime Minister Churchill agreed to restrict their use to retaliation only. Nevertheless, they might be used in a future war if such a decision is made by the President or the Joint Chiefs of Staff.

We should not ignore the potentialities of toxic chemicals or neglect planning and

training in their use. Such neglect might prove disastrous if toxic chemicals were unexpectedly used against us, or if the decision for our use of them should be made.

Micrometeorology is a study of weather on a small, local scale. It deals with weather phenomena at or near the surface of the earth. It is concerned with wind; temperature; humidity; cloud cover; precipitation; atmospheric stability along the surface of various types of terrain; and the influence of hills, streams, woods, towns, or other terrain or man-made features on these elements.

Detailed analysis of micrometeorology in the target area is an essential part of planning for use of a smoke or toxic gas. A reasonably accurate forecast of micrometeorological conditions at the target is extremely important in chemical warfare, since it affects the choice of munitions, aiming points, strength requirements of forces, and time of attack.

The presence of alternating patches of woods and bare soil introduces turbulence in the air. Air movement at the surface may be greatly deflected, even completely reversed, by the presence of lakes, hills, or valleys. Often surface air movement is completely reversed at night.

SMOKE

SMOKE is used to conceal. Concealment can prevent observations by the enemy, reduce the effectiveness of his fire, or hamper his operations by deceiving or confusing him.

Smoke used to prevent observations and otherwise interfere with hostile activity is called a *smoke screen*. If smoke is placed directly upon a target to deny vision and hamper enemy activities in the immediate

area, it is called a *blinding smoke*. If a vertical smoke screen is laid to conceal friendly troops or installations from enemy ground observation, it is called a *smoke curtain*. Smoke placed over, rather than upon, a target is called a *smoke blanket*. Sometimes it is desirable to cover a friendly area with a light concentration of smoke to prevent enemy observation from a distance yet permit local activity and observation. This is called a *smoke haze*.

30. Principles of Employment

Each situation determines the type of smoke tactics to employ. Each situation must be studied on the basis of the following information: the objective of the operation, the terrain, relative positions of the two forces, and the weather. After the conditions listed are evaluated, it is necessary to determine the point of release and the munitions required.

Smoke is valuable for signaling or marking. The Air Force uses signal smoke bombs or colored streamers for target identification, and ground units designate targets for supporting aircraft by means of artillery or mortar smoke shells. Colored smoke grenades, used according to a prearranged code, can identify front lines or friendly patrols.

Aerial smoke operations support ground forces in amphibious landings, river crossings, bridgehead assaults, airborne operations, protection of flanks, screening movements, withdrawals, armored operations, and target marking. Smoke can blanket anti-aircraft or searchlight positions and provide cover for low-altitude attacks.

Each operation dictates the type of smoke tactics required. Amphibious landings, for example, are usually best supported by smoke curtains laid near the beach; cover for low-level aircraft attacks might require a horizontal blanket laid at some predetermined altitude on the target approach line, or a small, dense blanket laid over specific anti-aircraft positions. In any case, the smoke must be sufficiently dense to provide concealment. In addition, a reserve of smoke munitions must be available to rein-

force weak spots in the smoke and to renew it as necessary.

In practice, reinforcing and renewing the smoke is the most difficult part of the operation. Because these missions are very dangerous for aircraft to perform, ground weapons should be used for the purpose, whenever adequate.

Smoke operations are primarily tactical, having only limited strategic value.

31. Smoke Agents

Several types of agents have been developed for chemical smoke munitions. Some exist as solids that must burn to produce a smoke cloud. The principal disadvantage of this type is the pillaring of smoke that results from the release of heat.

Liquid smoke agents are designed for spreading from aircraft spray tanks. Of the several liquid agents that have been developed, one is standardized.

Table 1 gives the standard smoke agents, the symbol and a brief description of each, and the air munition using each as a fill.

32. Smoke Munitions

There are two standard aerial smoke weapons: the M47A4 100-pound smoke bomb and the M-10 airplane spray tank.

M47A4 (100-Pound Smoke Bomb). This bomb consists of a thin-walled steel case containing 74 pounds of plasticized white phosphorus (PWP) and a bursting charge. The bomb has a vane-type fuze which arms and bursts on impact, scattering particles of white phosphorus as far as 100 yards (Fig. 4). Each particle of white phosphorus ignites spontaneously upon exposure to air, emitting an extremely dense white smoke.

When the air movement is moderate (10 to 20 m.p.h.), the smoke will form an effective screen for considerable distances downwind. In relatively still air, the smoke tends to rise because of the heat produced by the burning phosphorus.

The M47A4 bomb has limited incendiary, but considerable antipersonnel capabilities. If particles of the burning phosphorus land in combustible material, such as dry grass or wooden buildings, they cause a fire. If

TABLE 1.—SYMBOL AND DESCRIPTION OF STANDARD CHEMICAL SMOKE AGENTS AND MUNITIONS USING THEM AS A FILL

Symbol	Name	Description	Air chemical munition using agent as fill
WP	White phosphorus	A solid that burns when exposed to air, forming a very dense white smoke; the smoke tends to pillar vertically when released from bursting munitions	None
PWP	Plasticized white phosphorus	Particles of WP coated with a thin skin of rubber; this rubber coating decreases pillaring action	AN-M47A4 (100-lb. bomb)
HC	Hexachlorethane mixture	A solid that burns, producing a grayish-white smoke; because the smoke is formed by burning, it tends to pillar on release; toxic if sufficient quantities are released in enclosed places	None
FS	Sulfur trioxide solution	A liquid which, on exposure, forms a white smoke less dense than that from WP or PWP but slightly more dense than that from HC; does not pillar upon release; smoke irritates skin slightly; liquid FS splashed on skin, clothing, or equipment produces severe acid burns	M-10 airplane smoke tank



Fig. 4. Detonation of 100-pound WP bombs.

they land on personnel, they can ignite clothing and produce painful wounds. Such wounds are slow to heal because of the combined chemical injury and burn. For this reason, the M47A4 bomb is especially effective for use against antiaircraft batteries and searchlight positions, or for blanketing exposed enemy troops.

Smoke Tanks. Several types of spray tanks have been employed for aerial smoke operations. The current standard model is the M10 (Fig. 5). Spray tanks are highly effective in placing either a horizontal or a

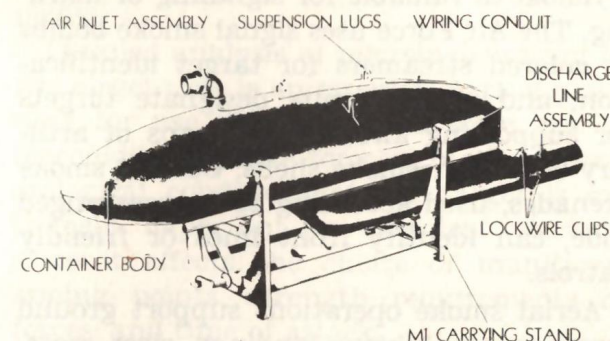


Fig. 5. An airplane smoke tank M10.

vertical screen at any altitude. The size of the screen and its duration depend upon the number of airplanes used. On the average, an aircraft carrying one M10 spray tank is capable of producing a screen about 500 yards long.

The standard agent used by the Air Force in smoke missions is a solution of sulfur trioxide in chlorosulfonic acid (FS), a heavy, oily, and corrosive liquid which reacts with the moisture in the air to produce an opaque white smoke. The smoke actually consists of extremely small droplets of dilute sulfuric and hydrochloric acids that eventually settle to the earth. If suffi-

ciently concentrated, this smoke is somewhat irritating to breathe, although harmless. The droplets are corrosive to both metal and cloth. For this reason the use of this smoke is carefully controlled near friendly units.

33. Smoke Operations

Being airborne, smoke is subject to all the atmospheric disturbances existing at the point of release. Ignorance of this simple fact explains most failures in smoke operations. Since smoke drifts downwind and moves away from the point of release, careful timing is essential. Frequently an error of a minute or two completely nullifies an otherwise successful operation.

Also highly important is the point of release. A smoke screen usually reaches its maximum obscuring value at a distance several hundred yards downwind from the point of release. Because the distance depends upon wind velocity and temperature gradient, these two principles should be followed: (1) The smoke should be released at a suitable distance upwind of the target to insure that the screen is fully developed over the target area. (2) Coordination is necessary to insure that screening of an area will not also obscure the target. For example, in blanketing an enemy anti-aircraft position, the smoke cloud must not obscure a bridge which is the target for the bombing attack.

Effective smoke operations can be conducted only by experienced pilots. Peacetime training in smoke operations assures the success of such missions in combat.

We have indicated some of the situations in which the Air Force can use smoke operations to support itself or another service. There may be occasions when another service can assist the Air Force by conducting smoke operations; for example, in defense of fixed installations, such as base depots, air depots, or airdromes.

The Army has developed equipment capable of generating large smoke screens that last for a long time. Units have been organized specifically for the employment of this equipment; for instance, they might be

used to protect major Air Force installations from hostile observation and attack.

INCENDIARIES

THE OBJECT of an incendiary attack is to start fires that will destroy the military usefulness of a target area. This may be done with various types of munitions, most of which are not, in themselves, capable of causing the damage desired. They are the matches used to start a fire. Combustible material must be in the target area, or the target is not suitable for incendiary attack. When they were properly employed, incendiary munitions were the most effective of the conventional weapons used during World War II.

34. Protective Measures

Using the British port cities as targets, the Germans directed, in 1940, the first large-scale airborne incendiary attacks of World War II. Although these attacks caused severe destruction, they were not decisive. Because of this threat, all the belligerents organized protective measures in their vulnerable communities. Basically, these protective measures include three types of organized activity: (1) training in fire fighting and organizing effective incendiary defense units, (2) providing special equipment for fire fighting, and (3) constructing firebreaks. Fire-fighting organizations and equipment are technical subjects beyond the scope of this manual, but firebreaks are described briefly.

Firebreaks may be used either for local protection or as area barriers. Designed to prevent the spread of fire within a single building or group of buildings, firebreaks for local protection include fireproof doors, fire-resistant walls, and wire-glass windows. Area barriers prevent the spread of fire across large areas. In this group of barriers are wide lanes (created by razing buildings) which separate the city into numerous fire divisions. Artificial firebreaks supplement natural and pre-existing firebreaks, such as rivers, railroad marshaling yards, parks, and other relatively open areas.

TABLE 2.—PERCENT OF DAMAGE BY OCCUPANCY ZONES¹

Zone	Average built-upness	Exposed areas burned
	PERCENT	PERCENT
Dense residential	45	72
Medium residential	30.6	46
Sparse residential	15.5	20
Mixed residential and manufacturing	35	44
Manufacturing	41	22
Transportation	14	15
Storage	37.6	22

¹Fire and the Air War, ed. Horatio Bond, National Fire Protection Association, Boston, 1946, p. 177.

In planning incendiary operations, the preventive and defensive measures used by the enemy must be taken into account. If he has local firebreaks, increased bomb tonnage is required on the target. The area firebreaks in enemy territory must be considered in determining aiming points and force requirements.

Two other factors are vital in planning incendiary operations. One is the combustibility of the target and the other is the ratio of the area covered by roofs to the total ground area, or the degree of "built-upness." Naturally, wooden buildings spaced close together will burn, and an empty reinforced concrete structure will not. An incendiary target usually represents types of structures between these extremes, and a detailed analysis must be made to determine degree of combustibility. In making such analyses during World War II, professional fire-prevention engineers, or persons of similar training and experience, gave valuable service. Table 2 shows the relationship between "built-upness" and the extent of damage in several Japanese areas. The table indicates that incendiary attacks are more effective against densely occupied targets than against targets containing widely spaced buildings; also, that residential areas are more susceptible to damage than manufacturing, transportation, or storage areas. The type of produce manufactured or stored would, of course,

greatly influence the vulnerability of such targets. Snow or rain, if heavy, would probably decrease the destruction caused by incendiary attack; if light, either would have little effect. Snow and rain decreased the effectiveness of attacks on Japanese cities by about 20 percent. Wind velocity is of major importance. Brisk breezes cause local fires to spread into a general conflagration.

35. Incendiary Agents

Incendiary agents ignite combustible substances by flame or by generation of heat. They may also produce casualties if they come in contact with the human body. Some are used as a primary incendiary for igniting secondary incendiary material; for example, the magnesium alloy in the casing of incendiary bombs.

Table 3 shows the standard incendiary fills, with the symbol, common name, description, and the type of air munition in which each is used.

36. Incendiary Munitions

There are four standard incendiary munitions: the AN-M50A3, a 4-pound thermate-filled bomb; the M74 10-pound PT-1-filled bomb; the AN-M47A4, a 100-pound PT-1-filled bomb; and the gasoline-gel-filled fire bomb.

AN-M50A3 (4-Pound Bomb). The principal incendiary bomb used in Europe during World War II was the small, hexagonal,

TABLE 3.—SYMBOL AND DESCRIPTION OF STANDARD INCENDIARY AGENTS AND THE AIR CHEMICAL MUNITIONS USING THEM AS A FILL

Symbol	Name	Description	Air chemical munitions using agent as fill
PT-1	Incendiary mixture PT-1	Grayish-black solid consisting of isobutyl methacrylate polymer, magnesium powder, oxidizing agent, petroleum distillates, and gasoline; burns fiercely and fast; difficult to extinguish	AN-M47A4 and M-74
NP	Incendiary oil NP	An incendiary gel composed of a thickener and gasoline; the thickener, formerly designated as napalm, is a mixed aluminum soap	Fire bomb
TH	Thermate	Basically a mixture of iron oxide, aluminum, and certain oxidizing agents; burns violently, producing a very high temperature; impossible to extinguish	AN-M50A3
Mg	Magnesium	A solid used as the body for 4-lb. incendiaries; burns brilliantly and at a high temperature	AN-50A3

4-pound AN-M50A3 (Fig. 6). This bomb is a hollow magnesium casing filled with thermate powder. The thermate filling is ignited by the action of the fuze on a small amount of a nitrate starter mixture. After the thermate burns for about one minute, it generates sufficient heat to ignite the magnesium casing, which burns for three to five minutes. This is usually enough time to ignite the combustible material in the area where the bomb falls. The blunt iron nose of the 4-pound incendiary bomb insures penetration of heavy roofs or one or more levels of multistoried buildings. The light sheet-iron tail stabilizes the bomb after release from its cluster.

M74 (10-Pound Bomb). The M50 bomb was found to have too much penetration to be effective against the lightly constructed buildings in Japanese cities. The bombs frequently went through the buildings and buried themselves in the earth, where they burned and caused little damage. For use against light buildings the 10-pound M74 bomb was developed (Fig. 7). This bomb could penetrate an average Japanese roof, but not too deeply.

The M74 bomb consists of a hexagonal sheet-steel casing filled with PT-1. The bomb also contains a small amount of white phosphorus, which ignites upon impact and then ignites the incendiary fill.

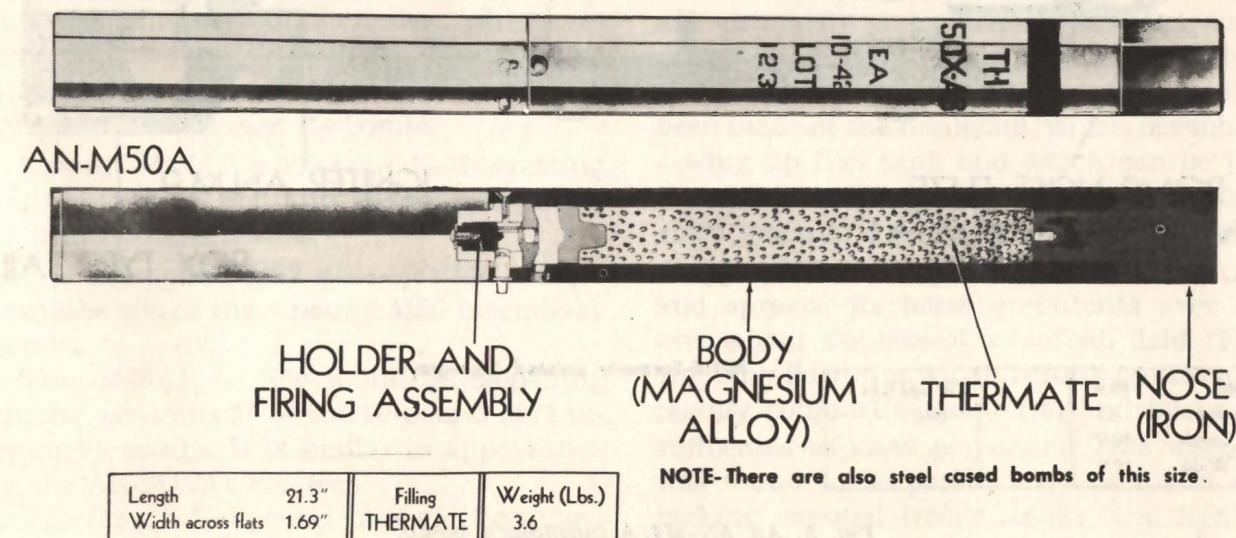


Fig. 6. A 4-pound incendiary bomb.

The bomb is stabilized by a metal tail fin, which is compressed into the body of the bomb to save space for packing in standard clusters. When the cluster opens and the bombs are released, the tail fins are forced out by a spring located in the tail well (see cut-away portion of Fig. 7).

The two small bombs, the M50 and the M74, are effective against small buildings (residences and stores), storage areas and industrial plants, and firmly built structures protected by four inches of reinforced concrete or its equivalent.

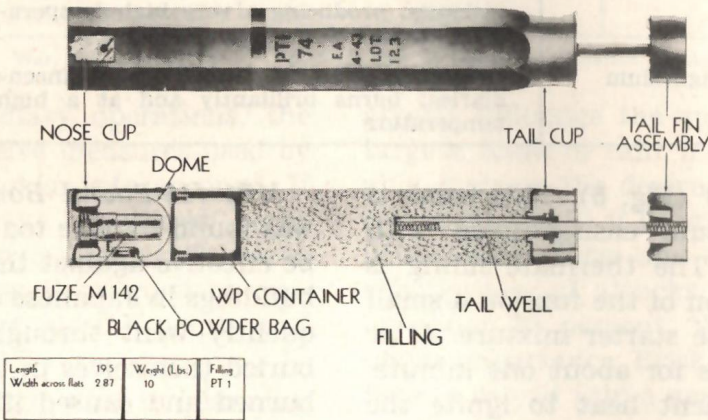
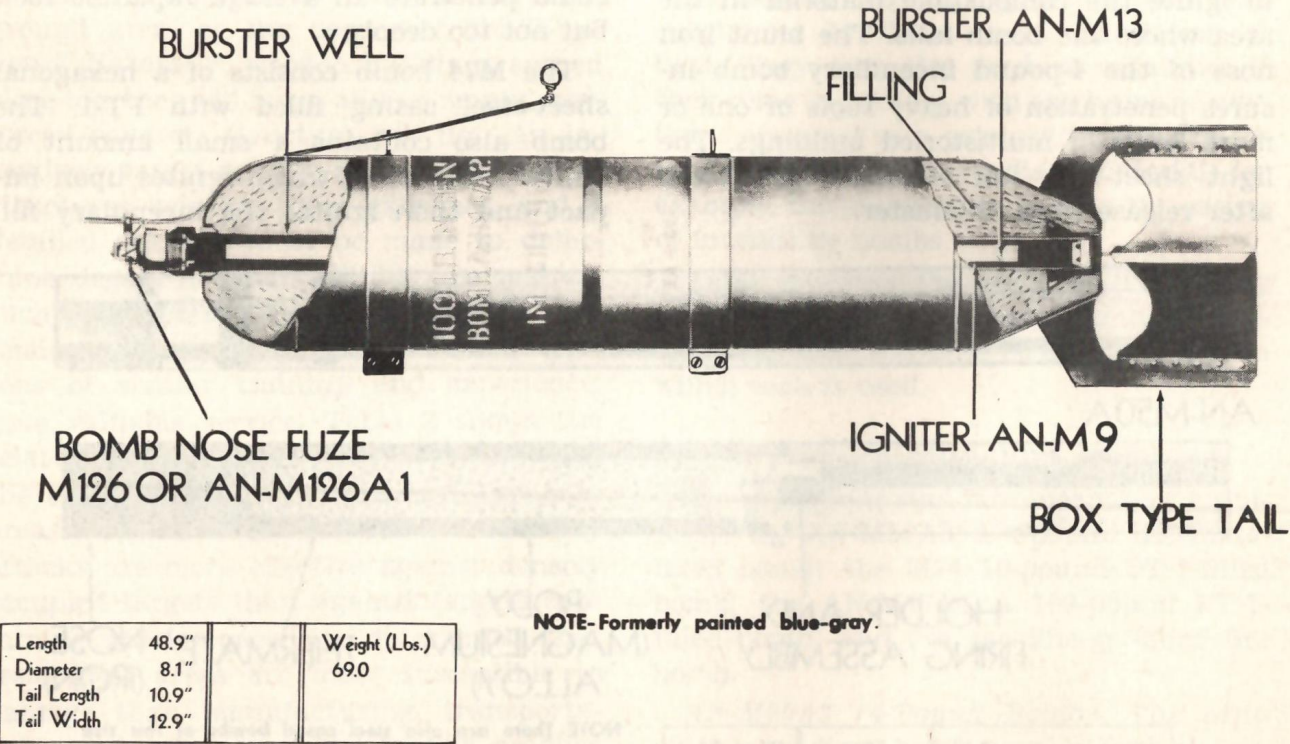


Fig. 7. An M74 incendiary bomb.

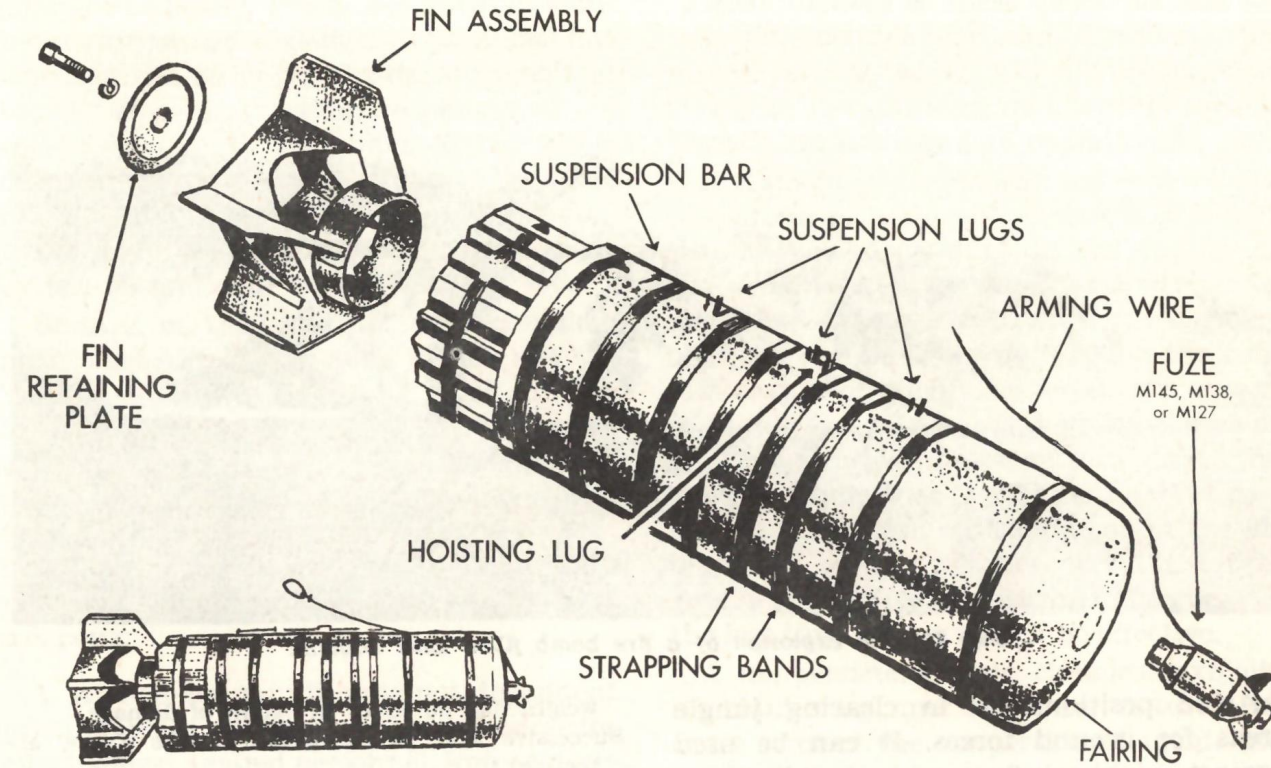


NOTE-Formerly painted blue-gray.

Fig. 8. An AN-M47A incendiary bomb.

AN-M47A4 (100-Pound Bomb). This incendiary bomb (Fig. 8) uses the same casing that is used for the M47A4 white phosphorus smoke bomb. The AN-M47A4, if dropped from 25,000 feet, can penetrate five inches of concrete. It contains 60 pounds of PT-1 fill.

Incendiary Clusters. The standard incendiary clusters are aimable from high altitudes. They are composed of adapters (metal parts which hold the cluster together), semicylindrical sheet-steel sides, fin-type tail assembly, and mechanical time



CLUSTER	WEIGHT (POUNDS)	LENGTH (INCHES)
CLUSTER, AIMABLE, INCENDIARY BOMB, AN-M17A1	463	56
CLUSTER, AIMABLE, INCENDIARY BOMB, M14A1	470	56
CLUSTER, AIMABLE, INCENDIARY BOMB, AN-M14	463	56

Fig. 9. The AN-M17A1, a 500-pound side-opening cluster.

fuze, in addition to incendiary bombs. Small incendiary bombs (4 and 10 pounds) are employed in such clusters.

There are two types of standardized clusters: the nose-ejection cluster, which releases its bombs through the forward end; and the side-opening cluster, which opens lengthwise to release its bombs.

The AN-M17A1, a 500-pound side-opening cluster (Fig. 9), contains 108 of the 4-pound M50 incendiary bombs.

The 500-pound M32 nose-ejection cluster contains 108 of the 4-pound M50 incendiary bombs.

The M20A1, a 500-pound side-opening cluster, contains 38 of the 10-pound M74 incendiary bombs. It is similar in appearance to the AN-M17A1 cluster.

The M31, a 500-pound nose-ejection cluster,

contains 38 of the M74 incendiary bombs. It is similar in appearance to the M32 cluster.

Fire Bombs. The bombs discussed above are primarily antimateriel weapons used chiefly in strategic attacks against industrial or urban targets. Considerable use has been made of the fire bomb, which resembles a wing-tip fuel tank and which can be jet-tisoned. It is filled with the incendiary mix (NP), popularly known as "napalm." When dropped in low-level attacks, the tank bursts and spreads its blazing contents over an area about the size of a football field (Fig. 10). The flash fire which results ignites any readily combustible material and burns or suffocates exposed personnel. This weapon was found to be particularly useful in attacking exposed troops, tanks, and lightly

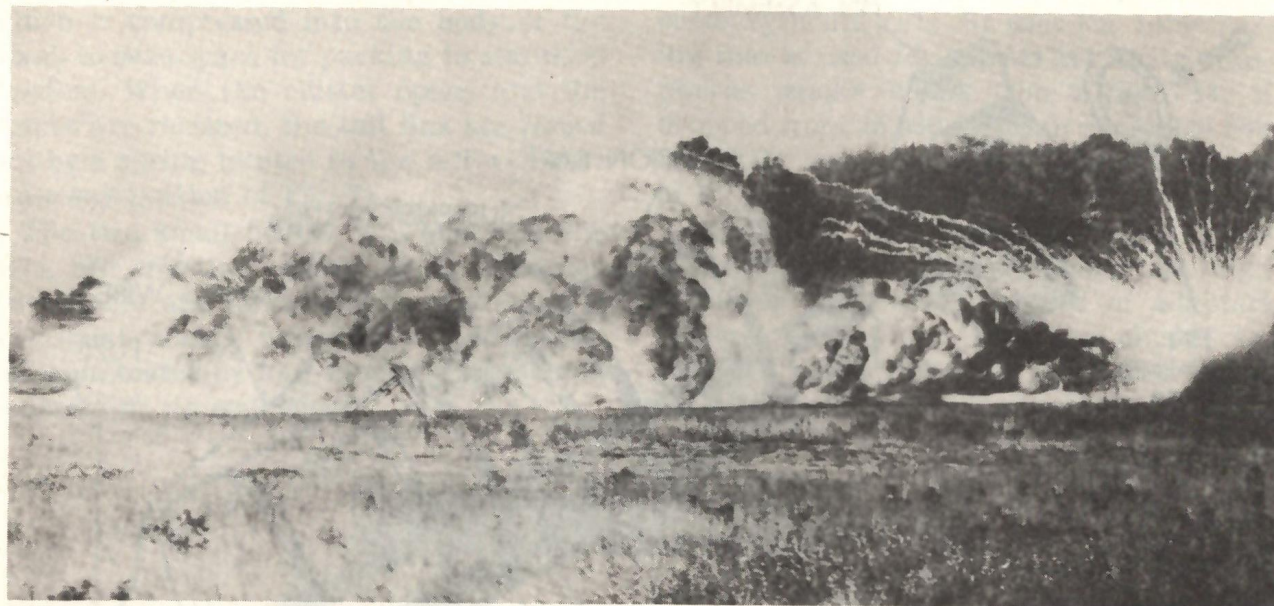


Fig. 10. The explosion of a fire bomb filled with napalm.

fortified positions, or in clearing jungle areas for ground forces. It can be used against highly inflammable buildings or supply dumps, although the smaller incendiary bombs, such as the M47 or M74, are more economical.

37. Factors Affecting Operations and Defense

During World War II, the following facts were observed about incendiary attacks:

Daylight visual bombing was found to be more effective than night attacks. [However, night attacks were highly effective, as proved by the attacks against Hamburg, Tokyo, and other cities.]

Multiple aiming points produced better bomb distribution and greater area of fire damage.

The axis of attack was found to be most effective when conducted at right angles to the wind.

Low-altitude attacks were more successful than high-altitude attacks.

The effectiveness of the attack was reduced as the time during which the bombs were dropped exceeded 2 hours.

Close intervalometer settings were the least successful, especially on heavy attacks.

Targets with 200 tons per square mile were as productive as targets with higher density, indicating general over-saturation.

Large targets sustained considerably more damage per ton of bombs than small targets.

Small incendiary bombs were more effective than large bombs on a ton basis.

The addition of HE bombs up to 10 percent by

weight had no effect on extent of damage. Successive and psychological attacks [were effective].²

Most incendiary attacks are directed against strategic targets, such as urban communities or industrial plants. For that reason, defense measures are primarily the concern of civilian defense organizations. Defensive operations protecting Air Force installations against incendiary attack are usually conducted by the base fire department. Additional personnel may be used in an emergency. After intelligence is obtained on the characteristics and capabilities of enemy incendiary munitions, fire defense units are trained in suitable techniques for extinguishing fires and minimizing their effects.

TOXIC GAS

TOXIC CHEMICAL AGENTS were not used during World War II. The Allied forces agreed to use chemical toxics only in retaliation. One possible reason that deterred Germany from using toxic gas weapons was that at the time when their use would have been to her advantage, she lacked the necessary air superiority.

Our only experience with gas was during World War I. Since then warfare has

²Ibid., pp. 174, 177.

changed radically. The development of techniques for the aerial delivery of weapons has thoroughly altered ground deployment and tactics. Mass destruction weapons, such as the atomic bomb, have affected the whole doctrine of the conduct of war. For these reasons, the tactics for, and even the doctrine of, the use of war gases are to a great extent theoretical.

Because of their nature, toxic chemical agents are of primary value for use against personnel. Other weapons of more conventional nature and of war-proven value, such as fragmentation bombs, are designed primarily to be used against personnel. The toxic chemical weapon maintains its place, nevertheless, because of two characteristics not possessed by other antipersonnel weapons:

1. A chemical munition is not dependent upon its point of impact or area of burst for effectiveness against personnel. Immediately upon impact, it forms a gaseous cloud which blankets the target area, searching out the defender wherever he might be—in fox-holes, natural shelters, or fortified pillboxes.

2. In addition to this unique property, the proper chemical weapon can, by contamination, render an area or position untenable or unusable for varying periods of time. Stated simply, a chemical weapon can be employed so that its primary effects remain on the target long after the weapon itself has been expended.

From the standpoints of effectiveness and economy, the aircraft is the best vehicle to use in delivering and employing toxic chemical weapons.

38. Principles of Employment

In general, the methods of employing toxic chemical munitions can be developed only after answers are found for the following questions: Where and when will the target present itself? What is the nature of the target and what is its state of preparedness against a gas attack? What weather conditions will exist at the target area at the time of the proposed attack?

With answers to these questions, the responsible commander can formulate his plan of attack, which will include number and type of munitions, number and type of aircraft required, and an operational plan.

If toxic gas is to be used, the commander will choose either a nonpersistent or a persistent type, depending on the nature of the target and the military requirements. A persistent gas is indicated if the military objective can be achieved through the contamination of enemy material, structures, or supplies, or by rendering a critical area or position unusable for a certain time. The length of time that the contamination persists depends both on the nature of the fill used and on the weather over the target area. For example, the warmer the climate, the less time will an attack be effective.

A nonpersistent toxic chemical exploits its blanketing and searching nature. Because some of the nonpersistent agents are insidious and extremely lethal, they can achieve surprise and a demoralizing loss of human lives. The chemical agents which adapt themselves to nonpersistent chemical attacks are, in general, lethal only if they reach the respiratory tract. Thus the element of surprise is of great importance to the attack. Given sufficient warning, any potential victim can adequately protect himself. If he does not have a gas mask he can leave the target area. If he is well-trained and properly outfitted, he can put on his gas mask in approximately 30 seconds and thus be completely protected.

If information is available concerning the degree of gas discipline and preparedness in the target area, the operational phase of a nonpersistent chemical attack can be planned.

Any tactic that the ingenious commander can employ to surprise the enemy contributes to the success of the attack. Usually the nonpersistent gas attack is completed within two minutes after the impact of the first munition. Night attacks are most effective, not only because of the accompanying surprise and confusion but because weather conditions at night are generally more favorable to chemical attack. Imme-

diately upon detonation, the nonpersistent agent goes into the form of a gaseous cloud. This cloud is most uniform and effective when wind speeds are low and there are strong inversions, conditions which occur most frequently at night.

Gas attacks, either persistent or nonpersistent, may be conducted against tactical or strategic targets. Tactical targets include troop concentrations (whether in combat, on the march, or in bivouac), major headquarters, service installations, pillboxes, tanks, bunkers, trenches, and similar installations that may offer protection against explosive munitions and fragmentation bombs.

Strategic targets include enemy industrial centers, harbors, and population centers of military importance.

39. Toxic Chemical Agents

The terms *war gas* or *poison gas* came into use during World War I when true gases, such as chlorine, were employed. Since then a great many chemical compounds, not necessarily gases, have been experimented with to determine their suitability as agents for toxic munitions. To be suitable, the compounds must be (1) highly lethal to man, (2) difficult to detect, (3) available in large quantities at a reasonable cost, (4) deliverable by militarily acceptable techniques, and (5) effective on the target under various field conditions. Under these criteria, a comparatively small number of chemical compounds have proved adaptable to military use. Most of those found acceptable are actually liquids at normal temperature and pressures, a few are true gases, and some are even solids.

The true gases are nonpersistent. Some valuable toxic compounds that are liquids at normal temperatures are nevertheless employed as a nonpersistent toxic agent. The agent is carried to the target as a liquid fill in a weapon. Upon impact, the liquid is blasted into small droplets. These droplets are immediately transformed into a vapor to form the "gas" cloud. Thus an agent

normally employed as a persistent agent can also be employed as a nonpersistent agent.

Some of the most valuable agents are toxic both as a vapor and as a liquid. As a vapor, they are lethal upon inhalation. As a liquid, they are lethal upon direct contamination of the skin. A few persistent agents even in vapor state are lethal when they contact the skin.

Table 4 gives the standard casualty-producing chemical agents, the symbol, common name, and description of each, and the air munition in which each is used as a fill.

Table 5 lists other toxic agents of current interest.

40. Toxic Chemical Munitions

Several munitions available for the conduct of aerial chemical warfare are the M70, M78, and M79 bombs, and the spray tanks.

M70A1 (115-Pound Chemical Bomb). The M70A1, 115-pound bomb (Fig. 11) was standardized late in World War II as a container for persistent agents, such as mustard. Upon impact, its explosive charge spreads liquid agents over a fairly large area and forms a small "gas" cloud. This bomb may be carried singly or clustered in groups up to four per bomb station. The only standardized filling for this bomb at present is distilled mustard.

Large Chemical Bombs. Two large chemical bombs are available for use with nonpersistent agents. These are the AN-M78 (500-pound chemical bomb) shown in Fig. 12, and the AN-M79 (1,000-pound chemical bomb) shown in Fig. 13. The standard fill for both of these bombs is phosgene.

Spray Tanks. The M-10 spray tank suitable for smoke agents (Fig. 5) is also suitable for use with persistent toxic agents. Extensive tests have shown that high-altitude spraying of toxic gas is impractical, largely due to excessive drifting and evaporation of the agent after release. Low-altitude attacks, using mustard released from spray tanks, are quite effective. The concentration of mustard vapor in the target area is

TABLE 4.—SYMBOL, PHYSIOLOGICAL ACTION, AND DESCRIPTION OF STANDARD TOXIC CHEMICAL AGENTS AND THE AIR CHEMICAL MUNITIONS USING THEM AS A FILL

Symbol	Name	Physiological action	Description	Air chemical munition using agent as fill
CG	Phosgene	Choking	Exists as a gas above 47° F. (boiling point) and as a solid below -155° F. (freezing point); highly toxic; has a delayed casualty effect; in low concentrations can kill or disable over long exposure periods; has odor of new-mown hay and exists as a colorless gas in the field; classified as a nonpersistent agent	M-78 and M-79 chemical bombs
GB	—	Effect on nerves	A liquid possessing a high boiling point and a low freezing point; extremely toxic and has immediate casualty effect; can kill or disable in very low concentrations over long exposure periods; has no odor; method of dissemination produces colorless gas cloud in the field; very toxic as a liquid contaminate; classified as a persistent nonpersistent agent	None
HD	Distilled mustard	Blistering action	A liquid whose boiling point is 442° F. and whose freezing point is 50° to 55° F.; either liquid or vapor produces delayed casualties by blistering action on eyes, respiratory system, or skin; can kill or disable in low concentration over long exposure periods; has characteristic garlic odor; used in the field as a liquid contaminate of exposed troops, areas, and materials or for producing casualties through vapor effects against troops protected only with a gas mask; classified as a persistent agent	M-70A1 chemical bomb and M-10 spray tank

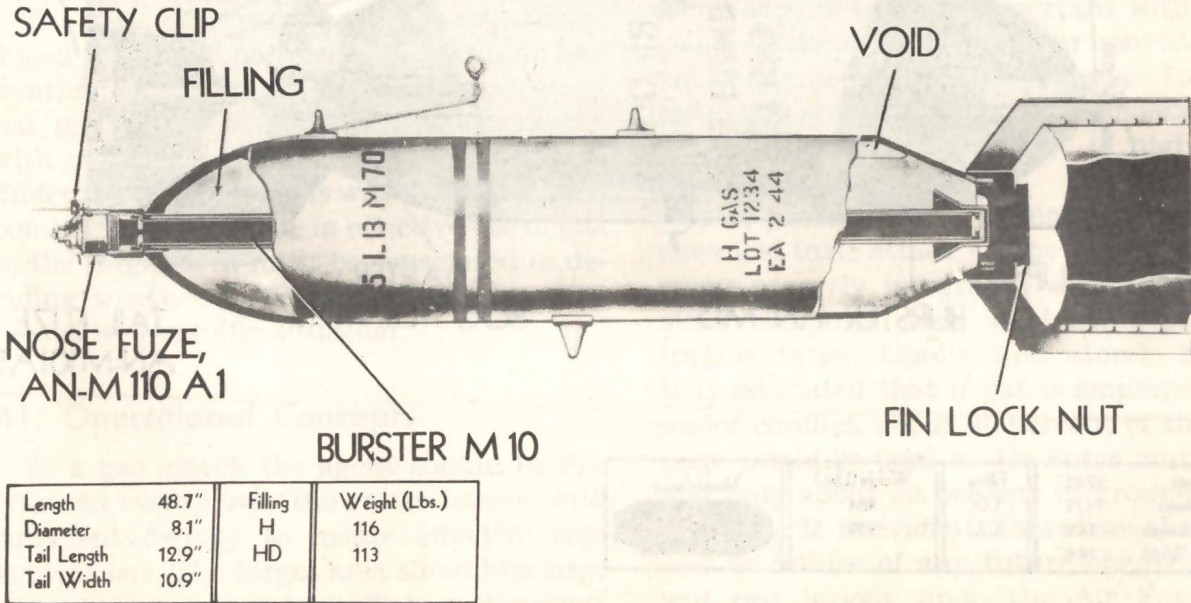


Fig. 11. A 115-pound chemical bomb M70.

TABLE 5.—SYMBOL, PHYSIOLOGICAL ACTION, AND DESCRIPTION OF OTHER TOXIC CHEMICAL AGENTS

Symbol	Name	Physiological action	Description
CK	Cyanogen chloride	Affects blood and nerves	Exists as a gas above 59° F. (boiling point) and as a solid below 20° F. (freezing point); intermediate toxicity but has rapid casualty effect upon exposure to lethal dosages; irritating if breathed in low concentrations; produces a heavy flow of tears; used as a colorless and odorless gas in the field; classified as nonpersistent
AC	Hydrogen cyanide	Affects blood	Exists as a gas above 80° F. (boiling point) and as a solid below 8° F. (freezing point); toxicity between CK and CG; has immediate casualty action upon exposure to lethal dosages; not effective in low concentrations, since body can continuously absorb and neutralize small amounts; has characteristic almond odor; used as a colorless gas in the field; classified as nonpersistent
L	Lewisite	Blistering action	A liquid whose boiling point is 374° F. and whose freezing point is 0° F.; produces delayed casualties in the same manner as HD; has characteristic geranium odor; used in the field in much the same manner as HD; classified as a persistent agent
GA	—	Affects nerves	A liquid of high boiling point and low freezing point; extremely toxic, with immediate casualty effect; can kill or disable in very low concentrations over long exposure periods; has a faint fruity odor; can be used as a liquid contaminate in the field or to produce a colorless gas cloud; classified as a persistent agent

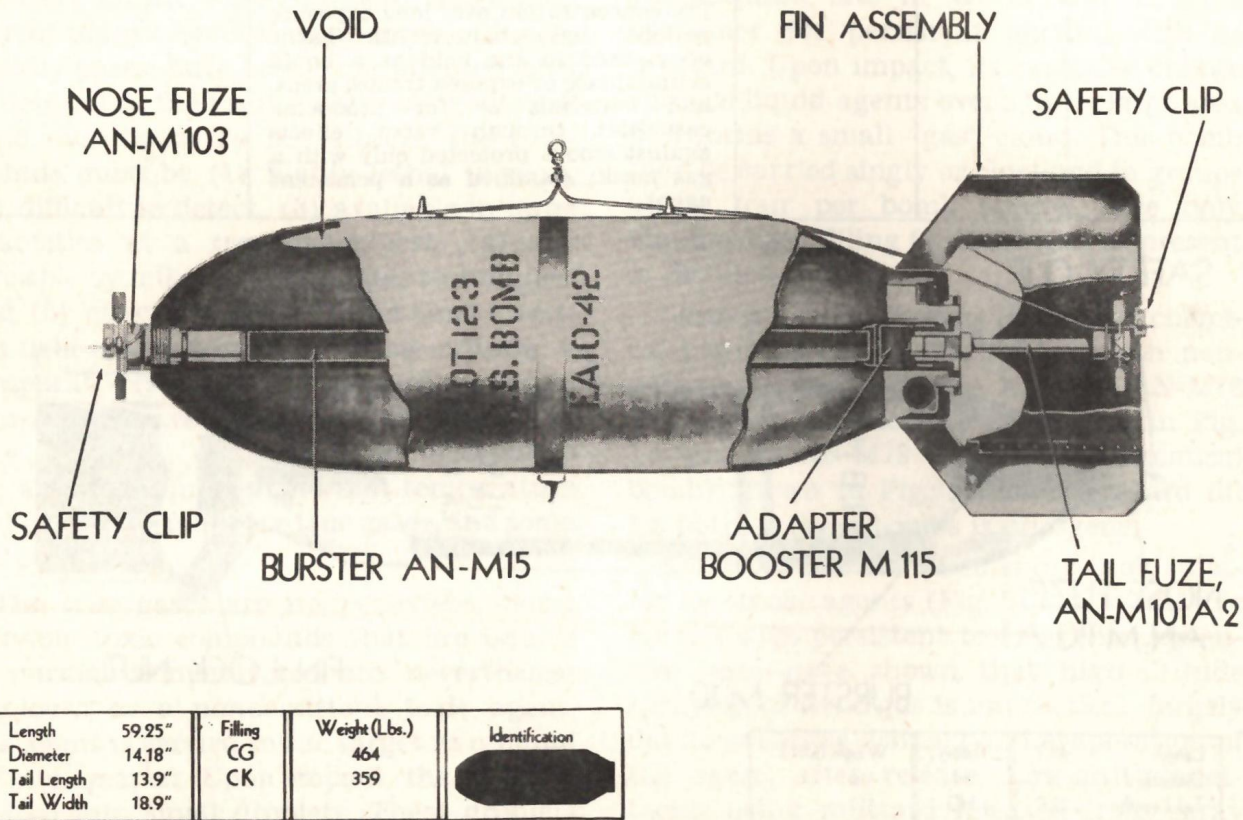


Fig. 12. A 500-pound chemical bomb AN-M78.

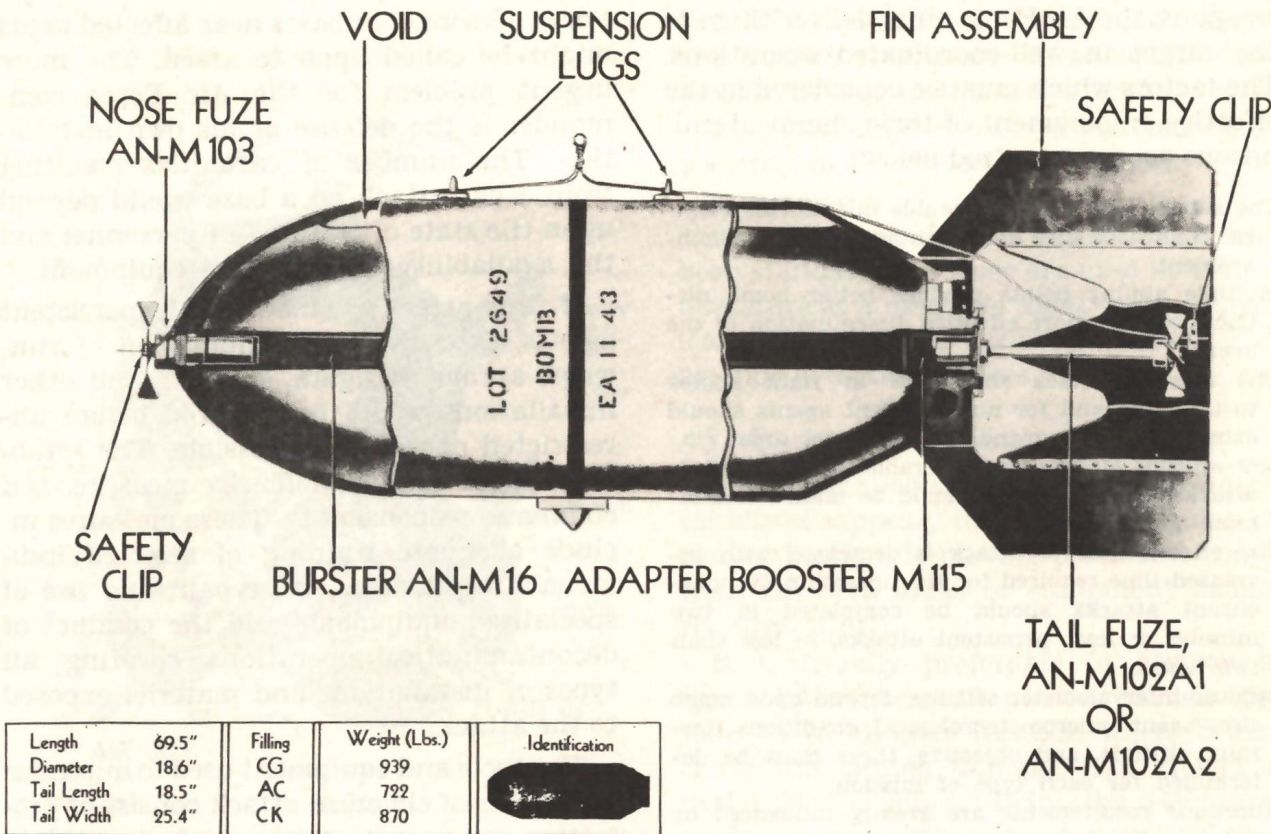


Fig. 13. A 1,000-pound chemical bomb AN-M79.

greater following a spray attack than following an attack of equal tonnage by M70 bombs.

The time of effectiveness, however, is reduced by spray operations. In warm or hot weather, effects of mustard spray rarely persist more than a few hours, as compared with one or more days following an attack under similar conditions with mustard-filled bombs. This difference in effective use of gas in the target area must be considered in deciding whether to use spray tanks or M70 bombs in a specific situation.

41. Operational Concepts

In a gas attack the agent should be distributed evenly over the entire target, with sufficient density to insure effective concentrations. The target area should be large enough to prevent immediate evacuation. Suitable targets may vary in size from a few

acres to several square miles. To cover a large target uniformly, multiple aiming point techniques should be employed. Pinpoint accuracy is less important with toxic gas munitions than with other conventional antipersonnel munitions, because the gas cloud will spread rapidly. Radar bombing in cloudy weather or at night is highly effective.

It is probable that in many instances a chemical toxic attack will be successful only when properly integrated with the use of other weapons, such as high explosives, fragmentation bombs, and atomic bombs. It is estimated that if gas is employed in a major conflict, about 80 percent of the tonnage would be used in Air Force munitions and only about 20 percent in ground force weapons. It is evident, therefore, that success or failure of any future chemical war will rest largely upon the Air Force. To realize the full capabilities of chemical

weapons, the Air Force must deliver them to the target in well-coordinated operations. The factors which must be considered in the effective employment of toxic chemical munitions are summarized below:

The surprise effect and favorable micrometeorological conditions give an advantage to night bombardment.

Multiple aiming points produce better bomb distribution and more effective dissemination of the agent.

The axis of attack should be at right angles to the wind and for nonpersistent agents should extend slightly upwind of the target area.

Low-altitude attacks are preferable to high-altitude attacks. Spray attacks should be made at minimum altitude.

The effectiveness of attack is decreased with increased time required for the operation. Nonpersistent attacks should be completed in two minutes or less; persistent attacks, in less than two hours.

Because intervalometer settings depend upon bomb size, agent, micrometeorological conditions, terrain, altitude, and objective, these must be determined for each type of mission.

Munitions requirements are greatly influenced by agent, micrometeorological conditions, and terrain.

Large targets require less bomb tonnage per unit of area than do small targets.

The addition of high-explosive bombs may be desirable for certain types of targets.

Successive attacks with reduced force requirements maintain effective concentrations in an area.

A chemical attack made by an air force according to the principles outlined would present a serious problem to the defender. Therefore we must consider ourselves as objects of such an attack and analyze defense problems.

Enemy attacks against our strategic targets would produce heavy casualties and important psychological effects. The problem of controlling a civil population exposed to gas attack, or even to the threat of one, would require extensive training of the people, an active and capable defense organization, and adequate stocks of protective equipment and supplies.

42. Responsibility for Defense Against Chemical Attack

The responsibility for urban defense rests with the civil authorities, although Air

Force personnel in bases near affected areas might be called upon to assist. The more urgent problem for the Air Force commander is the defense of his own installation. The number of casualties resulting from a gas attack on a base would depend upon the state of training of personnel and the availability of protective equipment.

If the attack is made with persistent agents, extensive decontamination of runways, aprons, hangars, shelters, and other installations would be required before unrestricted operation is possible. The establishment of suitable defensive measures is a command responsibility. These measures include adequate training of selected individuals in maintenance, repair, and use of specialized equipment; and the conduct of decontamination operations covering all types of installations and materiel exposed to the attack.

The tools and equipment used to minimize the effects of chemical attack consist of protective equipment, detection devices, identification kits, and decontamination equipment and supplies.

43. Protective Equipment and Self-Aid

The basic item of protective equipment, the standardized gas mask, provides complete protection of the respiratory system against all known toxic gases and biological agents if it is properly fitted to the individual at the time of the attack. This gas mask, the M9A1, has an M-11 cannister attached directly to the molded rubber face piece (Fig. 14).

Protection against skin contamination by the vapor of a blister agent is possible by treating quartermaster issue clothing with an impregnate. Unfortunately this impregnate is effective against liquid toxic chemicals only insofar as it makes the clothing impervious to liquid absorption.

Rubberized suits, completely impervious to vapor or liquid, are standardized and are available to special agent and munition handlers.

The carrying case of the M9A1 gas mask contains several items which provide a

been developed to detect liquid blister agents and liquid nerve gases. These liquids cause a color change in the indicator.

A standardized chalk changes color in the presence of heavy concentrations of blister gas vapors.

Various types of mechanical kits have been standardized. They are used by trained operators as a means of identifying a chemical toxic agent suspected to be present. They are not detection devices.

45. Decontamination

Since nonpersistent chemical agents rapidly disappear, they do not require decontamination. Removing persistent agents from enclosed areas or equipment usually requires effort.

It is usually preferable to destroy an agent by a chemical process rather than move it to another location where it may cause unexpected damage. The theory of destruction is simple: Bring the decontaminating agents into contact with the toxic substance so that they will react chemically, forming harmless products. Although simple in theory, actual accomplishment is often very difficult and expensive. It is comparatively easy to decontaminate a flat, nonporous surface, but persistent chemicals are not easily reached on concrete, brick, wood, or textiles. Liquid agents seep into cracks and spread around corners. Mustard gas and other persistent agents readily dissolve in oily or painted surfaces. Even the vapors tend to concentrate on such surfaces, which become dangerous without being directly exposed to the liquid agent.

The Liberty ship, the *Francis L. Lee*, is an example of a practical decontamination problem. This ship was used to bring several hundred tons of German mustard gas bombs to Edgewood Arsenal in 1946. During the voyage, a number of the bombs developed leaks and the ship became seriously contaminated. The decontamination operation required 51,000 man-hours of labor and the use of approximately 16 tons of decontaminating materials. In the process, much of the ship had to be torn out, part of it destroyed, and a major overhaul performed

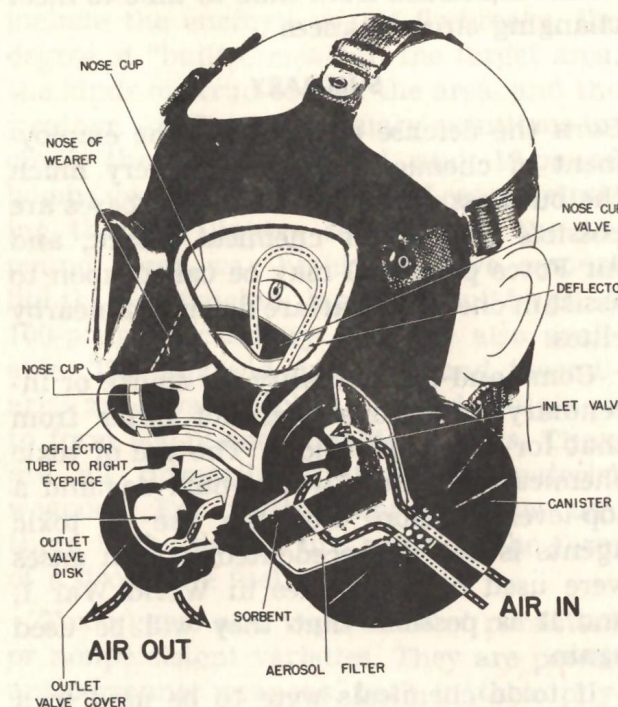


Fig. 14. Gas mask M9A1.

means of self-aid to a person whose protective equipment might be inadequate or improperly used.

There is a skin ointment and an eye ointment which are effective as liquid blister gas decontaminates if used soon enough after the attack. Self-aid against liquid nerve gas contamination consists of flushing the exposed area with water from a canteen or other source.

Also in the carrying case is an atropine syrette, which makes possible self-administration of an atropine solution to ward off the toxic effects of nerve gases. If a shot of atropine is administered soon enough after exposure, it reduces some of the toxic effects.

44. Detection Equipment

Because man's nose and eyes are no longer capable of detecting the presence of toxic gases, since many of them are colorless and odorless, some automatic means of detection must be devised. Some progress has been made in this field.

Certain kinds of paint and paper have

before it could go to sea again. Decontamination of an airfield in the combat zone would probably require as much manpower and much more decontaminating material.

Decontaminating Agents. A variety of substances can be used to destroy persistent chemical agents. These decontaminating agents include chlorine of lime, lye, strong soap, washing soda, or an issue preparation called DANC (Decontaminating Agent Non-corrosive).

Chloride of lime may be used, either as the unadulterated white powder mixed with earth or sand or in solution with water, to destroy persistent chemical agents, particularly mustard gas. Lye (sodium hydroxide), washing soda (sodium carbonate), or even strong soap may be used in solution for decontamination. Either chloride of lime or lye can be used on buildings, aprons, runways, or similar large surfaces on iron objects, such as the outer surfaces of trucks or guns. However, they are too corrosive for use on aircraft. DANC is suitable for decontaminating machined metal surfaces, but is less satisfactory than strong soap solution or soda on exposed portions of airplanes. The decontamination of delicate equipment, such as instruments and communication equipment, is especially difficult.

Decontaminating Equipment. A variety of sprayers, ranging in size from the 3-gallon apparatus that resembles a fire extinguisher to the 400-gallon apparatus mounted on a 2½-ton truck chassis, are available for decontamination operations. Dry chloride of lime can be spread over flat, contaminated areas, such as roads and runways, with various types of equipment.

Standing Operating Procedures. An effective chemical defense requires a high degree of training, availability of supplies, and teamwork. A basic assumption in chemical defense is that an Air Force installation must not be abandoned because of chemical attack, but must be returned to full operating efficiency in the minimum of time. Therefore, one of the early requirements for chemical defense is the development of a suitable plan. Bases usually pub-

lish this plan as an SOP. The SOP is usually supplemented by operations defense orders, which are issued from time to time to meet changing circumstances.

SUMMARY

BOTH the defense against and the employment of chemical warfare are very much the business of the Air Force. Air bases are possible targets for chemical attack, and Air Force personnel may be called upon to assist in chemical warfare defense in nearby cities.

Command responsibility for smoke or incendiary operations does not differ from that for other operations. The use of toxic chemicals in future wars would demand a top-level decision. But the use of toxic agents is not unprecedented; poison gases were used by both sides in World War I, and it is possible that they will be used again.

If toxic chemicals were to be used in a major conflict, about 80 percent of the tonnage would be used in Air Force munitions and only about 20 percent in ground force weapons. Incendiary attacks are mainly Air Force strategic operations. While ground weapons play an important part in smoke operations, the Air Force is also called upon for tactical smoke missions.

All chemical warfare agents fall into three classes: smoke, incendiary, and toxic.

Smoke is used mainly for concealment of friendly troops and installations, but it is also effective in signaling or marking, and in blanketing enemy positions. Smoke agents are either solids which burn or liquids which produce an opaque cloud. Standard smoke munitions for Air Force use include a 100-pound plasticized white phosphorus bomb and a spray tank which spreads liquid smoke agents. Effective employment of smoke demands skilled pilots and careful study of micrometeorological factors. In using smoke to defend air bases, the Air Force can call upon smoke generator units of the Army.

Incendiary munitions are the "matches" used to start fires in target areas. For the

attack to be effective, combustible material must be present in the target. Other factors affecting the success of incendiary missions include the enemy's use of firebreaks, the degree of "built-upness" of the target area, the kinds of structures in the area, and the weather. Air Force incendiary munitions include the small 4-pound and 10-pound bombs used in World War II. Less penetrating than its lighter counterpart, the 10-pound bomb was highly effective against lightly constructed Japanese buildings. A 100-pound incendiary bomb is also available. The 4-pound and 10-pound incendiaries are always packed in fuzed containers to form 500-pound aimable clusters. These are all primarily strategic antimateriel weapons. For tactical antipersonnel use, there is the deadly fire bomb in the form of a droppable fuel tank.

Toxic gases and vapors are of persistent or nonpersistent varieties. They are potent antipersonnel weapons, both in their physical effects and their powers of demoralization. Nonpersistent gases are effective because of the speed with which they can blanket an area; their use depends almost entirely upon the element of surprise. Persistent agents are useful as strategic weapons. As tactical weapons, they make areas untenable for the enemy.

Decontamination of areas saturated with persistent toxic agents is a slow, difficult, costly process. Aside from top-level considerations mentioned, the effective use of toxic weapons makes it essential that the commander weigh carefully a number of operational factors. The Air Force has avail-

able toxic chemical bombs ranging from 115 to 1,000 pounds, and the aircraft spray tank used to spread smoke agents can also be used to drop persistent toxic agents in low-altitude attacks.

Antichemical defense, the responsibility of the commander of the installation, involves the training of selected personnel in the use of specialized equipment, and the training of all personnel in the use of gas masks and other self-protective equipment, as well as the use of ointments and syrettes for self-treatment in case of exposure.

Decontamination of areas attacked with persistent agents requires skilled use of special equipment. Plans for the chemical defense of an installation are usually published as an SOP. The basic assumption is that Air Force installations must not be abandoned because of chemical attack.

REVIEW QUESTIONS

1. Who has command responsibility for initiating the use of toxic chemicals in a future conflict?
2. What is micrometeorology?
3. What are the chief uses of the plasticized white phosphorus bomb? What are its secondary effects?
4. Is the toxic chemical GB (see Table 4) classified as a persistent or a nonpersistent agent? What self-treatments are effective against it?
5. What agents are useful for decontamination of areas exposed to persistent gases? Which of these can be used on machined metal surfaces?

Biological Warfare

THERE have been new developments in conventional explosive bombs, aircraft armament, and chemical weapons; but in most cases these developments have been arrived at only after long operational experience. Even though atomic weapons are relatively new, we know enough about them, as you will see in later chapters, to be fully aware of their cataclysmic destructive powers. In the case of biological warfare, however, we have considerably less experience and knowledge. It carries big question marks. The terror inspired by biological warfare is largely the fear of the unknown.

Biological warfare is the intentional use of living organisms, or their toxic products, to cause disease or death in man, animals, or crops. Although biological warfare is not a new idea, it is assuming greater importance in military planning because of recent scientific advancements and increased international interest. Communist charges against the United Nations, or more specifically, U.S. troops in Korea, have brought biological warfare to the attention of the general public. The fact that biological warfare has not been used in Korea and that the accusations are completely false has in no way lessened the interest and curiosity of both military and civilian segments of our population. This chapter is written to satisfy some of this general curiosity and to inform you, as a member of our armed forces, of the concepts underlying this relatively new weapons system.

46. Historical Background

Disease has played a major role in the economic and military history of nations. Plague turned back the Crusaders at the gates of Jerusalem. It periodically scourged Europe from 800 to 1665. The last of these

outbreaks, in London, killed a quarter of the population of that city. Typhus defeated the Moors in their war against Spain. Pneumonia, dysentery, and typhus helped drive Napoleon out of Russia. A world-wide influenza epidemic from 1918 to 1920 is estimated to have caused the death of 20 million people. Malaria played a tremendous role in our own operations in the Pacific in World War II.

The Irish Famine in 1845 and 1846 was the result of a fungus disease which virtually wiped out the Irish potato crop. Because of this crop failure, more than a million people died of starvation and a half million more were forced to emigrate.

Crude attempts at biological warfare have been made throughout the history of warfare. Examples are the pollution of water sources with the bodies of dead animals and the catapulting of the bodies of plague victims into besieged cities. In June of 1763 the Indians along the Ohio River were attempting to drive the early settlers of western Pennsylvania and Kentucky back across the Allegheny Mountains. Sir Jeffrey Amherst, commander in chief of the British forces, suggested in a letter to his subordinate in command at Fort Pitt that he try to spread smallpox among the Indians. Accordingly, two blankets and a handkerchief from the smallpox hospital were presented to two Indian chiefs. Smallpox raged among the Delaware Indians, and historians have estimated that the epidemic which spread throughout various tribes in North America caused the death of one-half their population.

In World War I the Germans employed bacteria to start an epidemic of glanders among the horses of the Rumanian cavalry.

In 1940 and 1941 the Japanese were accused of dropping plague-infected fleas on Chinese cities. The validity of these reports has never been fully established. There were several cases of plague which occurred at this time in the city of Changteh, an area in which plague is not endemic.

As you can readily see, biological warfare does not fall in the category of tried weapons. The instances of its use have been too few, too specialized, and too poorly documented. Is biological warfare feasible as a weapon? Between the two world wars many articles were written on this subject, but most of them expressed doubt as to its value as a weapon. Some authorities today say it will never cause widespread disease and death among man, plants, and animals. Others maintain that it is a greater threat than the atomic weapon. This lack of agreement indicates that we have much to learn about biological warfare.

Biological warfare would probably produce effects ranging from relatively mild illness to death. The severity of the illness would depend on the agent used and the resistance of the host to that agent. An incapacitating illness might be the aim of biological warfare in antipersonnel attacks. This would tax medical and economic facilities more severely than would a large number of fatalities. In antianimal and anticrop attacks, death and destruction are preferable. In all forms of biological warfare a psychological reaction could be expected, and every effort would be made to exploit it.

47. Microorganisms Producing Disease

Microorganisms are living forms, usually microscopic in size. Many are composed of a single cell which is capable of carrying out all functions of life, including growth and reproduction. Some microorganisms resemble plant life, and therefore may be regarded as members of the vegetable kingdom. Others possess animal-like characteristics and are classified as animals.

Kinds of Microorganisms. The microscopic plants include *bacteria*, *fungi*, and

some *rickettsiae* and *viruses*; the microscopic animals are called *protozoa*. All microorganisms absorb their food through the cell wall. Reproduction is by binary fission. In this process the nucleus of the cell splits in half, then the cell splits, and two discrete cells are formed. The fungi are more complex multicellular plants. They reproduce by spores, which are microscopic single cells resembling seeds.

Microorganisms range in size from the viruses, which measure .01 to .25 microns (a micron is about 1/25,000 of an inch), to the largest fungi, which may be several inches in diameter. The rickettsiae measure about .5 micron, and the bacteria, 1 to 10 microns.

There are thousands of varieties of these microorganisms, but only a few (perhaps 200) are pathogenic, or disease-producing. This is the chief characteristic required of a biological warfare agent. Most pathogens are parasites—that is, organisms living in or on other organisms, or hosts. While living at the expense of the host, they reproduce and cause disease. They do this by destroying the cells of the host's body or by producing poisons (toxins) that destroy the cells.

Growth and Survival. Growth of microorganisms depends on a large number of factors, some of which we shall discuss here.

Since about 90 percent of the cell is water, moisture is essential to all microorganisms. Removal of even part of the water from a cell will result in changes in its functions and may eventually cause death. Food for the cell must be in a dissolved form in order to pass through the cell wall. Therefore moisture is necessary in the medium surrounding the cell.

Food is required for microorganisms, just as it is for ourselves. This food includes mineral salts, sugars, proteins, and vitamins. Species of microorganisms vary as to the food they are capable of utilizing. One of the problems of raising cultures is determining just what combination of food substances organisms require.

All microorganisms require oxygen. Some get free oxygen from the surrounding medium and are called *aerobes*. Others can utilize only chemically combined oxygen and are called *anaerobes*.

Microorganisms differ greatly in their ability to withstand variations in temperature. For each species, there is an optimum temperature for growth.

Light is not required for the growth of microorganisms; in fact, they grow best in shadow or darkness. Sunlight destroys them.

The time factor also affects the growth of microorganisms when they are placed in a new environment. There they require a period of adjustment known as the *lag phase*. During this period, little or no growth occurs. Then growth progresses at a logarithmic rate until a certain concentration of organisms is present. At this point the number of living organisms remains constant, but the number of actively reproducing ones steadily decreases. This is probably due to the poisoning of the environment by the organisms themselves.

A further aspect of the growth of certain microorganisms is *sporulation*, or the formation of spores. Sporulation is not a true factor of growth, but is a protective mechanism favorable to either reproduction or survival. Under adverse environmental conditions, such as dryness, excessive heat or cold, or lack of food, the cell forms a spore which contains the essential elements of life and which is surrounded by a tough outer wall. This spore may remain dormant for years and then, given a favorable environment again, produce an actively growing, reproducing cell.

Identification. Microorganisms may be identified in various ways. Generally they are classified according to source, environment, or the diseases they produce.

Within the laboratory, organisms may be identified by means of a microscope or by various techniques of staining. Biochemical tests may also determine the identity of the organisms. These tests use data relating to the physical and chemical processes by which living tissue is produced and maintained.

Another method of identifying organisms is by serological tests. The organisms produce antigens, such as toxins, which cause body cells to produce antibodies. A sample of blood serum is used for tests.

You can see that the identification of microorganisms may be a very complicated and lengthy process. This is one of the big problems in biological warfare defense, since both preventive measures and treatment of casualties depend on identification of the agent.

48. Infection and Immunity

When pathogenic microorganisms enter the host and multiply, infection or disease may result. There is a conflict between the host and the invading microorganisms. If the host wins, the organisms are destroyed; if not, the organisms continue to reproduce, causing fever, malaise, and other symptoms.

Infection and Incubation. *Virulence* is the relative power of an organism to cause disease in the host. It refers to the severity of the infection, which may vary from a mild, temporary disturbance to one resulting in death. Virulence is generally greatest when the organism is first discharged from a host, and least when it has been stored or has been removed from a host for a long time.

Virulence may depend on *invasiveness* or *toxicity* or a combination of both. Invasiveness is the ability of a microorganism to enter the host and to travel from one part to another. Toxicity is the quality of being poisonous and is a measure of the strength of the toxins produced by the organism.

An important aspect of biological warfare is the infective dose for a particular agent. It is the initial dose or number of organisms required to infect an average host. Theoretically, one organism can cause infection under the proper conditions. Actually, numerous organisms would be employed in biological warfare. In the case of organisms with a high virulence, however, a small initial dose might be effective. The resistance of the host to the disease would be another factor in determining the number of organisms in the initial dose.

Once organisms have entered the host, a period of time elapses before the symptoms of the disease become manifest. This lag is known as the *incubation period*. The organisms must establish themselves in the host and increase sufficiently to cause disease. The period of incubation may vary from a few hours to weeks and even months, depending on the virulence of the organisms and the resistance of the host. At the end of the incubation period the symptoms of the disease appear either suddenly or gradually.

The portal of entry of pathogenic organisms is of considerable importance in biological warfare. The principal portals are breaks in the skin, the respiratory tract, and the digestive system. Some organisms require specific routes of infection; others are capable of causing infection through two or more portals of entry.

Resistance of the Host. The ability of the body to combat pathogenic organisms is known as *resistance*. There are three lines of resistance against disease: the skin and mucous membranes, the cellular defenses, and the blood stream.

The skin and mucous membranes serve as a mechanical barrier against the invasion of microorganisms. In the respiratory passages, *cilia* (small hairlike projections) sweep the organisms toward the mouth where they can be swallowed or coughed up.

The second line of defense is found in the cells of the deeper tissues of the body. When organisms enter these deeper tissues, certain white blood cells (phagocytes) move to the site of the infection. They are capable of destroying the invading organisms. Also, a network of *fibrin* from the blood fluids collects around the area and isolates the battlefield. If the organisms overcome the phagocytes, they enter the lymph channels and are carried to the lymph nodes, where giant phagocytes (macrophages) destroy them. Swelling of the lymph nodes indicates the presence of this struggle.

In the third line of defense, the blood stream, there are several special substances which the body manufactures when stimu-

lated by invading organisms. *Antibodies* are produced which destroy or neutralize antigens. These antigens are products of the invading organisms, and antibodies are specific for particular antigens. Also, the liver, spleen, and bone marrow contain macrophages. The slower flow of blood in these organs provides greater opportunity for overcoming the pathogenic organisms.

Immunity. The resistance of the body of the host is sometimes developed to the state where it can prevent disease. Such resistance is called *immunity*. Immunological reactions operate in terms of antigens and antibodies, as described above. Immunity, however, may be either inherited or acquired.

Inherited immunity, a characteristic with which the host is born, makes possible a resistance to specific infections without the production of antibodies.

Acquired immunity is established after birth and may be either active or passive. The body acquires *active immunity* naturally through successful recovery from a disease, or artificially by means of the injection of antigens which stimulate the production of antibodies. Active immunity is artificially acquired, for example, from typhoid and tetanus shots. Usually of short duration, *passive immunity* may be either naturally or artificially acquired. Passive immunity that is given by the mother to the offspring before birth is naturally acquired. Passive immunity may be artificially acquired by injecting human or animal blood serum containing antibodies.

49. Biological Agents Affecting Man

Possible biological warfare agents include microorganisms, their toxic products, and certain chemical compounds. Only a few, however, meet the military requirements established for biological warfare agents. These requirements include the ability to cause disease in a host, economical production in adequate quantities, and stability in storage. Other desirable properties are difficulty of detection, capability of producing rapid and widespread disease, dif-

ficulty of protection and immunization, entrance through more than one portal, and a short incubation period.

Keeping these requirements and desired characteristics in mind, we now examine possible agents for use in biological warfare.

Bacterial Diseases. Among bacteria which might possibly be used against man are those producing tularemia, undulant fever, plague, glanders, and anthrax.

Tularemia is a disease that is generally contracted from infected rabbits. In naturally occurring cases the portal of entry is usually skin abrasions. The disease has a fairly low mortality rate, about 4 to 8 percent in untreated cases. Tularemia can also be contracted through the respiratory system and through eating infected animals. No satisfactory immunization for tularemia is available, but permanent immunity is conferred on those who have recovered from the disease. A small rod-shaped bacterium (*Bacterium tularense*) causes the disease. The incubation period averages 3 days.

Undulant fever, or brucellosis, is usually contracted by drinking infected milk, and is caused by bacteria of the *Brucella* genus. There are three forms: *Brucella suis*, a parasite of swine; *Brucella abortus*, a parasite of dairy cattle; and *Brucella melitensis*, a parasite of goats and sheep. All three forms of the disease are similar; a short acute stage is followed by a long chronic illness. Symptoms include headache, pain in muscles and joints, weakness, and recurring fever. The mortality rate is low, varying from 2 to 6 percent in untreated cases. Undulant fever may be contracted by direct contact with infected animals or by ingestion of infected dairy products. Undulant fever is not normally transmitted from man to man. The incubation period averages 14 days. Immunization for man is unsatisfactory.

Plague is highly epidemic, particularly in the presence of unsanitary conditions. It is endemic in the western portion of the United States, where a reservoir of infection is found in ground squirrels and other rodents. Caused by the organism *Pasteurella pestis*, plague has an incubation period

varying from 1 to 7 days. Anti plague serum and bacterial vaccines provide immunity for periods ranging from one to several months, depending upon which type is present. There are three types: (1) *Bubonic plague* is an infection of the lymphatic system causing ulcerated swellings, or buboes, at the lymph nodes in the armpit and groin. In untreated cases, the mortality rate ranges from 30 to 60 percent. As an infectious disease of rats, it is transmissible to man by the bite of fleas that are carried on rats. (2) *Septicemic plague*, known as the Black Death, is an infection of the blood stream causing large subcutaneous hemorrhages which turn black—hence the name. It is about 90 percent fatal in untreated cases. (3) *Pneumonic plague*, an infection of the respiratory system, has a mortality rate of 90 to 100 percent in untreated cases. This form of the disease is usually transmitted from man to man through the respiratory system.

Glanders, normally a disease of horses, is occasionally communicated to man. The organism is transmitted through breaks in the skin to produce a chronic form of the disease, and by inhalation to produce the acute form. When the site of infection is in the skin, a large spreading ulcer forms. In untreated cases, the chronic form is 50 to 70 percent fatal; the acute form, nearly 100 percent fatal. Glanders is caused by the organism *Malleomyces mallei*, one of the cocci, or spherical bacteria. No immunization is known for this disease. The incubation period is 3 to 5 days.

Anthrax, a disease of farm animals, may also infect man. It is caused by the organism *Bacillus anthracis*, which has the property of sporulation. The skin form of the disease begins with carbuncles and swellings at the site of infection. The pulmonary form is an infection of the lungs, contracted by inhaling the spores. In untreated cases the mortality rate is 25 percent in the skin form, and nearly 100 percent in the pulmonary form. Spore vaccines, reduced in virulence, are effective immunizing agents.

Viral Diseases. Psittacosis, encephalitis, and encephalomyelitis are among the virus-produced diseases that may be used in biological warfare.

Psittacosis, or parrot fever, is carried by birds of the parrot family and can be transmitted to man. The disease in man is an acute respiratory prostration with a mortality rate of 9 to 20 percent. The portals of entry are the respiratory tract and breaks in the skin. There is apparently some man-to-man transmission. The incubation period varies from 6 to 15 days. Measures for immunization have not been perfected.

Encephalitis and encephalomyelitis are produced by specific viruses. The clinical pictures of the two diseases are similar; they vary primarily in severity and rate of progress of symptoms. These acute diseases are characterized by inflammation of the three membranes that envelop the brain and spinal cord. Symptoms include fever, dizziness, stupor, tremors, prostration, and muscular incoordination. The virus is transmitted to man by the mosquito. The incubation period is variable, ranging from 2 to 15 days. The mortality rate is unknown, but probably will approach 60 percent in untreated cases. Widespread immunization is not practical at present.

Rickettsial Diseases. Among diseases caused by rickettsiae are epidemic typhus and Rocky Mountain spotted fever.

Epidemic typhus is transmitted mainly by body lice. Symptoms include severe headache, high fever, skin rash, and general body pains. It has an incubation period of about 12 days and a mortality rate upwards of 10 percent in untreated cases. Vaccine reduces risk of infection and lowers mortality rate.

Rocky Mountain spotted fever is transmitted by wood ticks and closely resembles typhus. Symptoms include fever, skin rash, and muscular pains. The incubation period lasts about 10 days, and the mortality rate is upwards of 20 percent in untreated cases. An egg-yolk vaccine is available and lessens chance of infection.

Protozoic Diseases. Most protozoa do not

produce diseases in man or animals, although specific types may cause amoebic dysentery, African sleeping sickness, and malaria. Difficulty of production and transmission make it unlikely that pathogenic protozoa would be useful in biological warfare.

Diseases Produced by Toxins. Toxins may generally be classified as any poisonous substance of microbic, vegetable, or animal origin. An example of a toxic substance produced by bacteria is botulinum toxin. It is the most poisonous substance known, more poisonous than cobra venom or curare. At least five types are known: A, B, C, D, and E. A, B, and E are toxic for man, causing botulism, an acute form of food poisoning. C and D are toxic for animals, and may possibly be toxic for man. In man, the poisoning is caused by eating food contaminated with botulinum toxin. Symptoms of the disease include fever, dizziness, nausea, double vision, and paralysis of muscles in the throat. Death is usually caused by respiratory paralysis. The mortality rate is directly related to the amount of toxin consumed. In untreated cases, the lethal dose is approximately .0007 gram. The use of botulinum toxoid provides active immunization.

50. Biological Agents Affecting Animals

The primary purpose of biological attacks against animals would be to reduce man's food supply, draft power, and transportation facilities. Agents are easily transmitted from one animal to another or from herd to herd. For that reason, epizootics (epidemics of animal populations) would be more easily established than epidemics among man.

Viral Diseases. Common virus diseases include foot-and-mouth disease, rinderpest, hog cholera, Newcastle disease, and fowl plague.

Foot-and-mouth disease is a highly contagious virus infection of cloven-hoofed animals. It is transmitted through contaminated feed, pastures, water, body wastes, and direct contact. Symptoms include acute

fever and blisters on the feet, on mucous surfaces of the mouth and cheeks, and on the udder. This disease causes a rapid loss of weight, a decrease in milk flow, and a lowered reproductive capacity. The mortality rate may be as high as 70 percent for cattle and swine. Quarantine of exposed animals and slaughtering of infected animals are the only effective controls.

Rinderpest is an extremely contagious and highly fatal disease of cattle, sheep, and goats. It is transmitted in the same manner as foot-and-mouth disease. Symptoms include croupous inflammation of the digestive tract, inflammation and ulceration within the mouth, and bloody diarrhea. Mortality varies from 25 to 100 percent. The use of specific serum induces immunity of short duration.

Hog cholera is a highly acute disease of hogs characterized by extreme weakness, blood poisoning, and severe hemorrhages. Contaminated food and water, hog pens, and excrement of diseased swine produce a rapid spread of cholera. The mortality rate may be as high as 90 percent. Effective immunization methods have been developed and are available.

Newcastle disease may infect all barnyard fowl, causing severe respiratory symptoms, stupor, twitching of the head, and possibly paralysis. Transmission is by direct contact and ingestion of water and food contaminated by infected feces. Mortality ranges from 10 to 100 percent. No satisfactory method of immunization has been established.

Fowl plague is a contagious and highly fatal disease of fowl, especially chickens and turkeys. It is characterized by hemorrhages in body tissue, swelling, and blood poisoning. It is generally transmitted by ingestion of food, water, and soil contaminated by infected fowl. Mortality varies from 20 to 80 percent. A satisfactory method of immunization has not been established.

51. Anticrop Agents (Living)

Anticrop agents are used to injure or destroy food, feed, fiber, oil, and medicinal or industrial crops. Nearly all of the micro-

organisms which would cause disease among plants and crops are classified as fungi. These fungal agents form large numbers of stable spores which are easily spread to produce epidemics among plants. Examples of fungi that are injurious to plants are late blight of potatoes and stem rust of cereals.

Late blight of potatoes attacks potatoes and tomatoes, causing large water-soaked lesions to form on the foliage. The leaves are destroyed and the yield is reduced. The spores of this fungal organism may also reach the tuber root of the potato and destroy the remainder of the crop. The disease may be initiated through infected seed stock. Control consists of using chemicals sprayed at weekly intervals, but it is very costly in time and machinery.

Stem rust of cereals attacks wheat, oats, rye, barley, and various grasses. The fungus causes pustules to form on the leaves and stem of the plant. Consequently, the plant loses an excessive amount of water, resulting in a reduced yield and shriveled grain. The inoculation of a plant area with rust is accomplished by dropping the spore on susceptible plants. The spore germinates and develops a pustule filled with spores. The pustule erupts, and spores are scattered by the wind to spread the infection.

Control of stem rust is possible by using fungicidal dusts, but the high cost of that operation may make it impractical. Rust-resistant strains of cereals can be planted. Eliminating the barberry bush, an intermediate host, would also help.

52. Anticrop Agents (Nonliving)

A second group of anticrop agents includes nonliving substances, such as chemical growth regulators. Such chemical compounds destroy the plants outright. For example, 2,4-D (2,4-dichlorophenoxyacetic acid) injures broad-leaved plants such as cotton, beans, sugar beets, sweet potatoes, flax, Irish potatoes, and soybeans. It may be applied by spraying or dusting. Some or all of these symptoms appear within 24 hours after contact: Plant stems and leaves begin to twist and bend. The foliage dries completely. Plant stems swell, and watery

buds appear, although new shoots will not develop. The covering of plant roots may slough off, exposing wet, stringy cores that later dry up. These chemical compounds are effective anticrop agents even when applied as sparingly as .05 pound per acre; however, they are nontoxic to man or animals. No method of stopping the action of these chemicals is known. Once the symptoms appear, plant injury cannot be treated. There is no permanent harmful effect on the soil since the toxic properties are lost in several months.

53. Employment of Biological Warfare

In this chapter we indicate how man, animals, and crops are susceptible to disease, and cite a few diseases that might lend themselves to the purposes of biological warfare. We do not attempt to evaluate the agents thoroughly or compile a complete list of possible microorganisms. Let us now consider how such agents might be used in warfare.

The primary objective of the offensive employment of biological warfare would be to produce diseases in man, animals, or crops. An attack of this nature would lower the vitality of manpower, reduce the quantity of food, divert medical and industrial forces from the war effort, and lower morale and the will to fight.

The effects from biological warfare can, to a large degree, be controlled by the selection of agents. Factors to consider in selecting agents are the degree and length of incapacitation, the mortality rate, the susceptibility of the enemy population, the contagion of the disease, and the rapidity of its action. In the employment of agents these factors should be considered: the ease or difficulty of detection, the degree of protection provided enemy personnel, the efficiency of munitions for disseminating agents, and the potential hazard to our own personnel.

It is difficult to develop munitions for disseminating biological warfare agents because organisms are alive and fragile. Munitions which may be adaptable to the delivery of agents are bombs, spray tanks,

artillery and mortar shells, and rockets and missiles of a similar nature. Biological warfare also appears to lend itself extremely well to attack by sabotage. Contamination of food and water supplies by covert means might be very effective.

In the dissemination of biological warfare agents, particle size is important. If infectious material is blown or sprayed as an aerosol cloud, in all probability the respiratory system is intended as the portal of entry. The problem then is to determine what size droplet or particle best enters and remains in the respiratory tract. It is believed that particles of 1 to 5 microns are the most effective. Smaller particles are exhaled, and larger particles are filtered by the body's natural defenses. The size range of 1 to 5 microns is similar to that of the bacterial cells but is a little larger than that of the viral and rickettsial bodies naturally encountered.

In biological warfare, as in the employment of other weapons, the element of surprise is important. If the enemy has taken adequate defense measures, the effects of an attack might be minimized.

It is reasonable to assume that biological warfare, if properly employed, might produce heavy casualties among personnel and animals, and large-scale destruction of crops. The use of contagious agents might increase the incidence of infection in a given area by 20 percent or more. Destruction of crops might seriously deplete the food supply for man and animals. In addition, the use of biological warfare would probably produce important psychological effects. It is not likely, however, that biological attacks would cause epidemics virulent enough to sweep away a large nation, nor is it probable that such attacks would determine the outcome of a conflict without the use of a balanced force of other weapons.

If we were to employ biological warfare, we might be faced with the possibility of retroactivity. When we use a weapon—whether biological, atomic, or chemical—in a combat zone, we take the calculated risk of injuring our own personnel. In

biological warfare the risk would, of course, be lessened if we possessed immunizing or therapeutic skills to supplement our protective equipment.

Biological warfare is mainly strategic in nature. Due to the danger of retroactivity and the time lag of the incubation period, it is probable that biological warfare would not be employed in the combat area. Industrial areas might be primary antipersonnel targets for biological warfare attack, either alone or in conjunction with other weapons. Other targets might be concentrations of animals and fields of grain and food crops. The effects of such attacks probably would not be felt immediately but would become evident over a period of time. This type of attack against the enemy's food supply would be comparable to a blockade of his country or the siege of a smaller area.

In a tactical situation involving a retrograde movement of our forces, biological warfare might be employed to retard the enemy. It might also be used to reduce selected strong points or small fortified islands and to neutralize air and naval bases.

54. Defense Against Biological Warfare

Protection against biological warfare is of two types: (1) immunization and (2) use of protective devices. Immunization of personnel and animals would effectively reduce the incidence of certain diseases, but there are diseases for which we have no immunizing agent. Protective devices include special clothing, masks, and collective protectors. Clothing can be made impermeable to particles or droplets. If gas masks are used properly, they provide adequate protection for the respiratory system. Collective protectors that work on the same principles as gas mask canisters could protect a room or building so that the occupants would not have to wear individual protective equipment.

Detection of agents is a difficult problem in defense against biological warfare. An overt attack might be relatively easy to detect—not so an attack made by saboteurs.

The first indication might be an increased incidence of disease. Regular examination of food, water, and air might give early indications but would be an expensive undertaking. There is no easy solution to this problem.

Once a biological attack has been detected, immediate decontamination is necessary. Food and water can be made sterile by boiling. Although food in cans will not be contaminated, containers should be sterilized before opening. If the attack has been made with an aerosol cloud, it may also be necessary to decontaminate buildings, vehicles, clothing, and even streets. Effective sterilizing agents include formaldehyde, phenol, sodium hypochlorite, and DANC. Boiling of cotton clothing would also be effective.

All the suggested defense measures aim to prevent the spread of diseases. The last line of defense would, of course, be medical treatment of the afflicted. We must remember, however, that an abnormally heavy demand upon doctors, nurses, hospitals, and medical supplies would tax our resources severely and would in itself be one of the enemy's objectives.

SUMMARY

FAR FROM BEING mere scare talk, biological warfare is a grim possibility. It is a subject very much in the public mind because of the trumped-up Communist charges that the United States engaged in germ warfare in Korea. Even though these charges are false, it is essential that we realize the possibilities of this form of warfare, since it may be employed in the future.

Throughout the history of mankind, diseases have played an important role in warfare. Practically all epidemics had a natural cause, although a few instances occurred where organisms were deliberately used. Populations were periodically plagued by sickness and death. Recurrent failure of food crops resulted in starvation. Because the economic life of a country may be undermined by such catastrophes, nations are investigating biological warfare as a possible supplementary weapons system.

Biological organisms are living bodies. Their environment must include moisture, food, oxygen, and proper temperature to sustain life. Because of these requirements, storage and dissemination are difficult.

To cause disease, microorganisms must enter the host, whether man, animals, or plants. In man and animals, the portals of entry are breaks in the skin, the respiratory tract, and the digestive system. In plants, disease is brought about by direct contact of the agent with the stem and leaves.

Some antipersonnel agents which may be used in biological warfare are organisms that cause tularemia, undulant fever, plague, glanders, anthrax, psittacosis, encephalitis, typhus, and Rocky Mountain spotted fever. Botulinum toxin, a nonliving substance, may also be used. Antianimal agents may include organisms causing foot-and-mouth disease, rinderpest, hog cholera, Newcastle disease, and fowl plague. Anticrop agents might include organisms producing late blight of potatoes and stem rust of cereals and nonliving chemical compounds.

These agents may be disseminated by means of bombs, spray tanks, shells, rockets, and missiles. In all probability, biological agents will be employed only over targets of a strategic nature. This is because of the danger of injuring our own personnel and the time lag which precedes illness.

Defense against biological attacks includes immunization; use of individual protective equipment; and decontamination of food, water, equipment, and facilities. Medical treatment of the afflicted would be the last line of defense.

REVIEW QUESTIONS

1. What are antigens?
2. What military requirements have been established for biological agents?
3. What measures can be taken against stem rust of cereals?
4. What are the principal drawbacks to the tactical use of biological warfare?

Elementary Principles of Atomic Energy

TO UNDERSTAND the practical problems of atomic warfare, you must first understand the elementary principles of atomic energy. This chapter explains those principles on a layman's level. Succeeding chapters describe the logistic and operational problems which confront the Air Force in its employment of atomic weapons.

The atomic age began secretly in the fall of 1939, when certain scientists informed President Roosevelt of their belief that the release of atomic energy was possible. According to them, atomic energy could be freed in either a controllable reaction to provide a source of continuous energy, or in a rapid reaction to produce an atomic explosion. What knowledge and experimental data led them to this conclusion?

The chain of knowledge was begun centuries ago. We cannot retrace its history through every experiment, theory, and test. Our aim here is to discuss only certain critical ideas which scientists had to understand if progress toward the release of atomic energy was to continue.

55. Early Concepts of the Structure of Matter

Man has always had an intuitive belief that nature is basically simple. He has long believed that elements were composed of certain fundamental building bricks. From the time of the Greek philosophers and throughout the Middle Ages, he thought that all materials in the universe were composed of four basic building bricks: earth, air, fire, and water.

Gold, for example, was said to contain all four elements. It was a solid; therefore it had earth in it. It was not the heaviest

material known; therefore it had some air in it. Because of its malleability, it had some water in it; because of its color, it had a large portion of fire in it.

Another example was wood. Being solid, lighter than some materials, and somewhat flexible, its constituents were believed to be earth, air, fire, and water. When wood was burned, the fire element was being released. With that element lost, the wood no longer appeared in its usual form, but had instead the characteristics of ashes.

This concept of the structure of material held well into the seventeenth century. Slowly, over the next two centuries, experimental techniques improved and more data became available.

One of the most surprising experiments performed to refute the earth-air-fire-water theory of matter was that of burning wood in an enclosed space. The mass of both the wood and the air was measured, prior to the burning and after the complete combustion, and it was found that the total mass of air and wood did not change as the wood burned. This meant that fire, believed to be a constituent of the wood, was not coming out and disappearing. Instead a process was occurring between the wood and the surrounding air. This process gave off fire but did not appreciably change mass.

56. Present Theory of the Structure of Matter

During the 1600's, 1700's, and early 1800's, the idea developed that the material universe was composed of a limited number of basic elements which, in various combinations, produced the wide variety found in materials. At first, scientists isolated and identified certain characteristics of only a

few of these basic elements. There was a gradual emergence of the idea that the material universe was composed of 92 basic elements.

In 1869 a Russian chemist, Dmitri Mendeleev, proposed the currently accepted periodic table, which he based upon the idea that in the orderly progression from the lightest to the heaviest element, there is a periodicity—a recurring sequence—in the chemical properties. In Table 6 the atomic numbers of the elements are shown to increase in a progression from hydrogen to helium, to beryllium, and so on. Also, when they are arranged in this order, the elements in any one vertical column show a similarity of chemical properties. Mendeleev was so sure of this theory that, where there was yet no element identified for a particular atomic number, he left a blank in the table and predicted that the mass number of the element was between the mass number of the preceding and succeeding elements. Further, he defined the chemical properties, in general, as being similar to the other elements in the same column. As the ability to isolate and determine chemical properties improved, the blank spaces left by Mendeleev in the original periodic table were gradually filled in.

Let us review briefly the fundamentals of chemistry and physics. These are necessary steppingstones to an understanding of Mendeleev's periodic table and of atomic science.

An *element* is a substance, like iron, gold, silver, and oxygen, which cannot be chemically reduced to, or built up from, a simpler substance. Its smallest unit is called an *atom*, which for a long time was believed to be indivisible.

Two or more elements may exist in a fixed ratio in a *compound*, the smallest unit of which is a *molecule*. Water, for instance, is a compound. A molecule of water consists of two atoms of hydrogen and one of oxygen. We can also speak of free, uncombined atoms as molecules. Both molecules of compounds and uncombined molecules can exist in a *mixture*, such as the air we breathe, which consists of about 78 percent

nitrogen and about 21 percent oxygen, plus small amounts of other gases, all intermingled as free molecules. There is no such thing as a molecule of air.

The formation or division of molecules is very frequently accompanied by a release of energy. Sometimes, as in the case of iron combining with oxygen to form rust, the reaction is so slow that the release of energy is imperceptible. On the other hand, a bit of heat applied to a mixture of hydrogen and oxygen can stimulate these two elements to combine, forming water so rapidly that the release of energy produces a flash and bang. In this rapid reaction the *potential energy* of the hydrogen and oxygen atoms is momentarily released as *kinetic energy*, some of which is dissipated in the air, and some is locked up again as potential energy in the new water molecules.

The fundamentals outlined represent good nineteenth century science, but they are still workable and valid. Modern discoveries have gone beyond them but have not refuted them.

The idea that the universe is composed of less than a hundred elements (building bricks or atoms) is consistent with man's intuitive belief in the simplicity of nature. In the 1890's scientists wondered if matter could be further reduced. They asked: Are not the elements, the atoms themselves, composed of different combinations of even fewer and more fundamental building bricks? The search for the answer to this question began to bear fruit.

Two particles were identified that were much smaller than any of the atoms of elements and that had no properties related to the elements from which they came. They were called *electrons* and *protons*.

The electron is a particle with a negative electric charge; the proton, a particle with a positive electric charge. When protons were placed near protons, or electrons near electrons, a force of repulsion appeared. But when electrons were placed near protons, a force of attraction appeared. In addition to having electrical properties, these particles were found to have size and mass.

TABLE 6.—PERIODIC TABLE OF THE ELEMENTS AND SOME OF THEIR ISOTOPES

(Figure to the left of the symbol is the atomic number of the element; figures shown below each element represent the mass numbers of the isotopes; mass numbers shown in boldface represent radioactive isotopes)

		Group 0		Group I		Group II		Group III		Group IV		Group V		Group VI		Group VII		Group VIII	
Family:		A		B		A		B		A		B		A		B			
Period	Series																		
1	1	¹ H Hydrogen 1 2 3																	
2	2	² He Helium 3 4		³ Li Lithium 6 7		⁴ Be Beryllium 9		⁵ B Boron 10 11		⁶ C Carbon 12 13		⁷ N Nitrogen 14 15		⁸ O Oxygen 16 17 18		⁹ F Flourine 19			
3	3	¹⁰ Ne Neon 20 21 22		¹¹ Na Sodium 23		¹² Mg Magnesium 24 25 26		¹³ Al Aluminium 27		¹⁴ Si Silicon 28 29 30		¹⁵ P Phosphorus 31		¹⁶ S Sulfur 32 33 34 36		¹⁷ Cl Chlorine 35 37			
4	4	¹⁸ Ar Argon 36 38 40		¹⁹ K Potassium 38 39 40 41		²⁰ Ca Calcium 40 42 43 44 46 48		²¹ Sc Scandium 45		²² Ti Titanium 46 47 48 49 50		²³ V Vanadium 51		²⁴ Cr Chromium 50 52 53 54		²⁵ Mn Manganese 55		²⁶ Fe Iron 54 56 57 58	
5	5			²⁹ Cu Copper 63 65		³⁰ Zn Zinc 64 66 67 68 70		³¹ Ga Gallium 69 71		³² Ge Germanium 70 72 73 74 76		³³ As Arsenic 75		³⁴ Se Selenium 74 76 77 78 80 82		³⁵ Br Bromine 79 81			
6	6	³⁶ Kr Krypton 78 80 82 83 84 86		³⁷ Rb Rubidium 85 87		³⁸ Sr Strontium 84 86 87 88		³⁹ Y Yttrium 89		⁴⁰ Zr Zirconium 90 91 92 94 96		⁴¹ Nb Niobium 93		⁴² Mo Molybdenum 92 94 95 96 97 98 100		⁴³ Tc Technetium 96 99 101		⁴⁴ Ru Ruthenium 96 98 99 100 101 102 104	
7	7			⁴⁷ Ag Silver 107 109		⁴⁸ Cd Cadmium 106 108 110 111 112 113 114 116		⁴⁹ In Indium 113 115		⁵⁰ Sn Tin 112 114 115 116 117 118 119 120 122 124		⁵¹ Sb Antimony 121 123		⁵² Te Tellurium (120) 122 123 124 125 126 128 130		⁵³ I Iodine 127			
8	8	⁵⁴ Xe Xenon 124 126 128 129 130 131 132 134 136		⁵⁵ Cs Cesium 133		⁵⁶ Ba Barium 130 132 134 135 136 137 138		Rare Earths ^a 57-71		⁷² Hf Hafnium 174 176 177 178 179 180		⁷³ Ta Tantalum 181		⁷⁴ W Wolfram 180 182 183 184 186		⁷⁵ Re Rhenium 185 187		⁷⁶ Os Osmium 184 186 187 188 189 190 192	
9	9			⁷⁹ Au Gold 197		⁸⁰ Hg Mercury 196 198 199 200 201 202 204		⁸¹ Tl Thallium 203 205		⁸² Pb Lead 204 206 207 208		⁸³ Bi Bismuth 209		⁸⁴ Po Polonium 210		⁸⁵ At Astatine 211 216 218			
10	10	⁸⁶ Rn Radon 222		⁸⁷ Fr Francium 223		⁸⁸ Ra Radium 225 226		89 Ac Actinium 225 227		90-98 Rare Earths ^a									

If atoms of the same element have different masses, a heavy particle with zero electrical charge must exist. This particle would be within the nucleus contributing to the mass of the atom without modifying the number of its orbiting electrons and, therefore, without changing its chemical properties. This particle, called the neutron, has a mass approximately equal to that of a proton but a zero electrical charge.

It follows then that the mass number of an atom is determined by the number of protons and neutrons within the nucleus, and the chemical properties of an atom are determined by the number and arrangement of the orbiting electrons.

With these three fundamental particles—the proton, the electron, and the neutron—the structure of all elements can be explained. An element may have atoms with different masses, due to the presence of more neutrons in some than in others. Argon, for example, has atoms with mass numbers of 36, 38, and 40. These atoms are isotopes of the element argon. It has been found that most elements have atoms of different masses; therefore, most elements are mixtures of isotopes. Another example may be found in Fig. 16, which shows the various isotopes of hydrogen. An understanding of the existence and composition of isotopes was necessary before the atomic bomb could be produced.

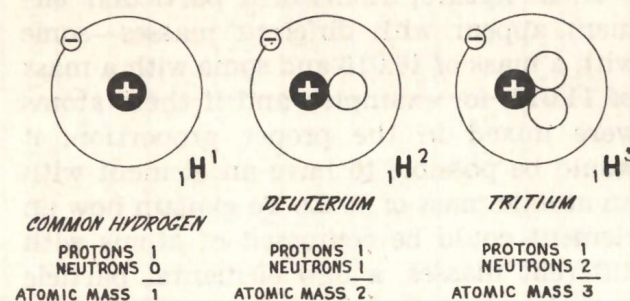


Fig. 16. Isotopes of hydrogen.

58. Radioactivity

Another important contribution to the knowledge leading to the atomic bomb was made in 1896 by a French physicist, Henri Becquerel. His discovery of natural radioac-

tivity is reputed to have been made in the following manner: He was investigating the relation between sunlight, the phosphorescence of some salts of uranium, and a photographic plate. He was ready to perform the experiment. Although the day was cloudy, he nevertheless exposed the plate to sunlight. The next day was also cloudy, but again Becquerel exposed the plate to sunlight. Each night he carefully wrapped the photographic plate and placed it, with the uranium salts, in his desk drawer. He then decided to develop the photographic plate, expecting to find only a faint image, because there was so little sunlight. Upon developing the plate, it was discovered that the plate had been very heavily exposed. He then placed uranium salts near a wrapped photographic plate. Again the plate appeared to have been heavily exposed, when developed.

Natural Radioactivity. Becquerel's experiment led to the discovery of natural radioactivity. Further experiments proved that there were particles and energy emanating from certain elements. The particles were called *alpha* and *beta* particles, and the energy, *gamma rays*. By allowing these particles and rays to pass through a magnetic and electric field, it was possible to learn something about their nature. The alpha particles were found to be fairly massive and to have a positive electrical charge, whereas the beta particles were found to be very light and to have a negative charge. The gamma rays were not influenced by the magnetic or electric field and were therefore assumed to be electromagnetic in nature, similar to visible light.

Later experiments proved that the alpha particles are the nuclei of helium atoms (Fig. 17), being composed of two protons and two neutrons, with no orbiting electrons at the time of emission. The beta particles were proved to be the fundamental negative particles of electricity, the electron. Gamma rays were confirmed as electromagnetic rays. They are similar to radio waves, visible light, and X-rays, with this chief difference: gamma rays have a much

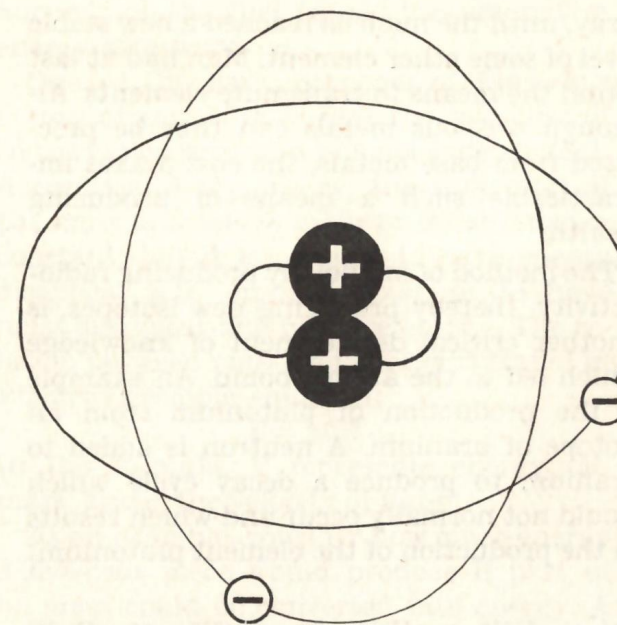


Fig. 17. Helium atom, showing two orbital electrons, and nucleus consisting of two protons and two neutrons.

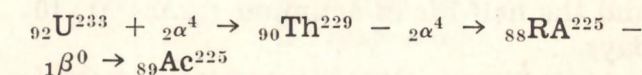
higher frequency (Fig. 18) than the majority of those listed above.

It was found that certain isotopes of some elements are not stable (Table 6) but modify their nuclear structure by shooting out a particle. Some of these nuclei get rid of an alpha particle; others fire out a beta particle or an electron. Since the electron is assumed to be coming from one of the neutrons within the nucleus, the atom appears to gain an additional proton by this process, and a transmutation of the element results.

Several radioactive decay series have been isolated and identified, as for example in uranium. One isotope of uranium has an atomic mass of 233 (written $^{233}_{92}\text{U}$). The 92 means that there are 92 protons within the nucleus, hence a plus charge of

92 on the nucleus. Normally there would be 92 orbiting electrons. The number 233 means that the atom has a total of 233 protons and neutrons within the nucleus. Since the nucleus is known to have 92 protons, it must have 141 neutrons.

This isotope of uranium decays by firing out an alpha particle:



The alpha particle, being the helium nucleus, has a plus charge of 2 and a mass number of 4: $2\alpha^4$. If this uranium atom loses approximately four mass units, it has a mass number of 229. If it then loses two positive charges, it has a net charge of 90. This is a thorium isotope: $^{229}_{90}\text{Th}$. This isotope, also unstable, loses an alpha particle. The atom then has a mass number of 225 and a charge of 88. This is a radium isotope: $^{225}_{88}\text{Ra}$. This atom is also radioactive but loses a beta particle rather than an alpha particle. Since the beta particle is an electron, the mass number of the atom remains 225. But the charge changes from 88 to 89, because one of the neutrons changes into a proton and an electron within the nucleus, and it loses its counterbalancing negative particle, the electron; and the atom gains one positive charge. This element is actinium, which is also unstable. This atom continues losing particles and modifying itself into new elements until it reaches an isotope of lead, which is stable.

The rate of each of these processes of radioactivity is defined in terms of the amount of time necessary for half of the atoms present to be transmuted. This time is called the *half life*. If there are one million atoms of uranium $^{233}_{92}\text{U}$ present, half

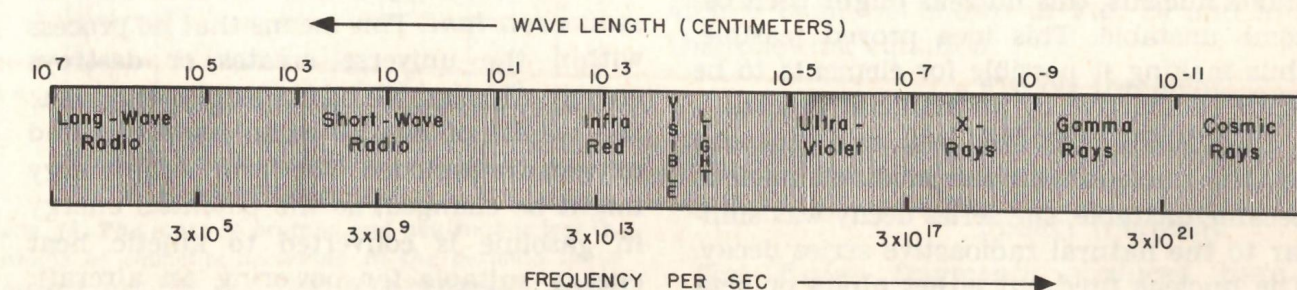


Fig. 18. Simplified electromagnetic spectrum.

of them will transmute themselves into thorium in one half life. The actual half life for the uranium isotope is 162,000 years. This means that one pound of this isotope of uranium will, in 162,000 years, be reduced to only one-half pound of ${}_{92}\text{U}^{233}$. The half life of thorium (${}_{90}\text{Th}^{229}$) is 7,000 years; the half life of radium (${}_{88}\text{Ra}^{226}$), 15 days; and the half life of actinium (${}_{89}\text{Ac}^{227}$), 10 days.

At times an excited atom emits a particle, and energy is released in the form of a gamma ray. An excited atom may also release energy in the form of a gamma ray without emitting a particle. In natural radioactivity, alpha and beta particles and gamma rays can be detected and checked against a decay series similar to the one described.

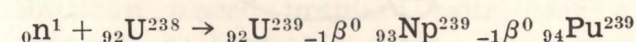
When it was known that natural radioactive elements release energy, the possibility of using these elements as a source of power was considered. There would have to be an increase in the rate at which these elements release energy if they were to provide power. A series of experiments attempted to modify the half life of natural radioactive elements. The half life remained constant under all conditions, including those of extreme temperature, strong magnetic fields, and strong electric fields. It became apparent that this method of obtaining energy was not practical.

Artificial Radioactivity. Since no means was found to speed up natural radioactivity, the next step was to produce radioactivity artificially. It appeared that certain nuclei were unstable and that this instability was related to the number of protons and neutrons they contained. It was suggested that if a neutron could be forced into a normally stable nucleus, this nucleus might then become unstable. This idea proved feasible, thus making it possible for elements to be made radioactive by an artificial process.

If a neutron was fired into, and captured by, the nucleus, and the modified nucleus became unstable, the series decay was similar to the natural radioactive series decay. The nucleus fired out either alpha or beta particles or a gamma ray, or a particle and

a ray, until the nucleus reached a new stable level of some other element. Man had at last found the means to transmute elements. Although precious metals can thus be processed from base metals, the cost makes impracticable such a means of producing wealth.

The method of artificially producing radioactivity, thereby producing new isotopes, is another critical development of knowledge which led to the atomic bomb. An example is the production of plutonium from an isotope of uranium. A neutron is added to uranium to produce a decay cycle which would not normally occur and which results in the production of the element plutonium:



59. Theory of Relativity

In 1905 Dr. Albert Einstein published his theory of relativity. It covers all physical phenomena and is exceedingly complex in its full mathematical presentation. Certain portions, however, are not too difficult for the lay mind, and they contribute much to our understanding of the atomic bomb.

Prior to Einstein's theory of relativity, scientists had accepted certain laws of conservation. One such law is that *the total mass of the universe remains constant*. Stated simply, no matter what man does to modify the state or condition of matter, he can neither create nor destroy it. No process in the universe creates or destroys matter by chemical means. The experiment in which the total mass of wood and air in an enclosed space remained the same after the wood was burned illustrates this law.

Another conservation law is that *the total amount of energy within the universe remains constant*. This means that no process within the universe creates or destroys energy. An example has already been given: the release of energy when hydrogen and oxygen are exploded. The form of the energy might be changed, as the potential energy in gasoline is converted to kinetic heat energy suitable for powering an aircraft, but the total amount of energy before the

burning of the fuel equals the amount of energy afterward.

One of the basic concepts of Einstein's theory of relativity is that the two laws of conservation are valid but not independent. According to the theory, the sum total of the mass and energy in the universe remains constant, but it is possible to have energy disappear and produce mass, or to have mass disappear and produce energy. The relation between mass and energy is stated in Einstein's simple equation:

$$E = Mc^2$$

In the formula, E represents energy; M , mass; and c , the velocity of light.

As an example, consider how much energy a five-cent piece would produce if part of its mass could be converted into energy. A five-cent piece weighs approximately 5 grams. If one-fifth of the weight of a nickel could be changed into energy in one hour, the energy released would be equivalent to 30 million horsepower. (The B-36 has approximately 44,000 horsepower, and the YB-60, approximately 80,000 horsepower.)

60. Source of Energy for the Atomic Bomb

The atomic bomb is an actual example of the tremendous conversion of mass into energy, as predicted by Einstein.

As yet, there is no means available for directly converting mass into energy, but

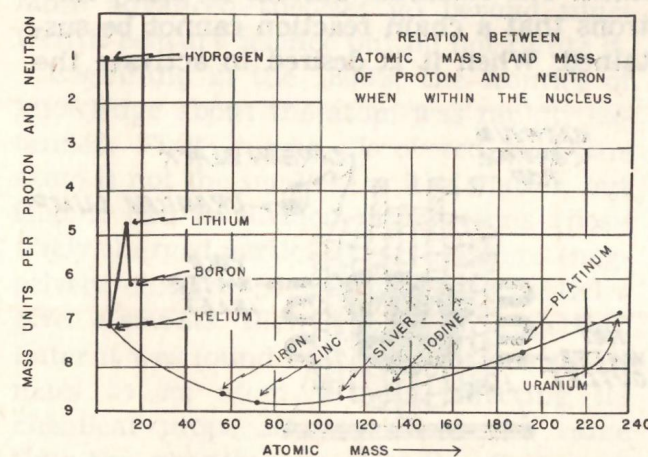


Fig. 19. The mass of protons and neutrons is less in atoms of elements occurring in the periodic table around iron, zinc, and silver than in atoms of platinum and uranium.

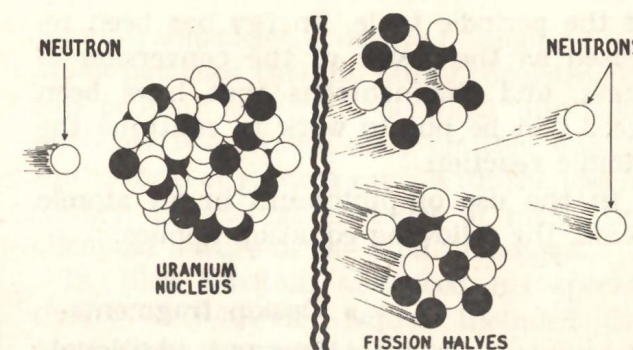
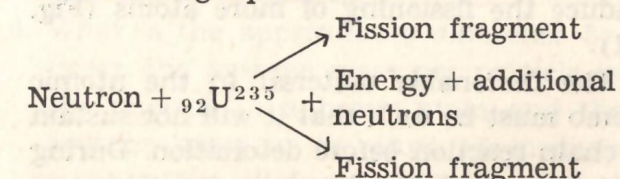


Fig. 20. Uranium fission illustrates splitting of a U-235 nucleus by a neutron, with formation of fission products and additional neutrons.

nature has provided a gradual means for making this conversion. It is found that neutrons and protons have a greater mass in the nucleus of a fairly heavy atom than in the nucleus of a medium-weight atom. Thus, the mass of protons and neutrons is less when they are in atoms of elements occurring in the periodic table around zirconium, tellurium, and cesium than when they are in atoms of platinum, uranium, and heavier elements (Fig. 19).

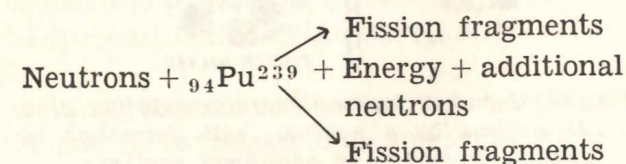
It seems that some of the mass of these protons and neutrons is converted to energy to hold the nucleus together. Therefore, the more closely bound atoms are those of elements around iron, zinc, and silver. This explains why the mass of the protons and neutrons in iron, zinc, and silver atoms is less than the mass of protons and neutrons within other atoms or in the free state. If an atom of uranium is broken down, or goes through the fission process, so that it forms two nearly equal parts, producing atoms near zirconium, tellurium, or cesium, this difference in the mass of the particles will appear as energy, in accordance with Einstein's equation, $E = Mc^2$. This process is employed in the release of energy by the atomic bomb, as shown in Fig. 20 and in the following equation:



The fission fragments produced have atomic numbers that fall around the middle

of the periodic table. Energy has been released as the result of the conversion of mass, and the neutrons that have been freed can be put to work to continue the atomic reaction.

In the use of plutonium in an atomic bomb, the following equation applies:



The energy released from a plutonium reaction is greater than that released from a uranium reaction; also, the number of neutrons available to produce further reactions is greater in plutonium than in uranium. Theoretically, plutonium is a more energetic fuel for atomic energy than uranium.

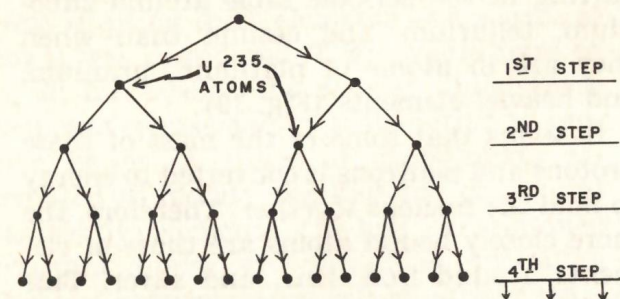


Fig. 21. Steps in the fissioning of U^{235} .

The *fission process* is the breaking of an atom into nearly equal parts, with an accompanying release of energy. Although only a small amount of energy is released by the fission of one atom, the fissioning of a large number of atoms may release a vast amount of energy. Notice that *both reactions give off neutrons, which were also necessary to start the reaction*. This gives us the possibility of producing a chain reaction, in which each atom that fissions will induce the fissioning of more atoms (Fig. 21).

The fissionable material in the atomic bomb must be such that it will not sustain a chain reaction before detonation. During the time that the bomb is inactive, any neutrons present or those produced from a few atoms fissioning, must travel out of the

mass of the fissionable material without interacting with the plutonium or uranium to produce more neutrons. At the time of detonation, the fissionable material in the bomb is rearranged so as to start and sustain a chain reaction.

The quantity of fissionable material that will sustain a chain reaction is defined as a *critical mass*. In the atomic bomb, the aim is to produce a maximum release of energy in a minimum amount of time. Therefore, the process of providing a critical mass is accomplished as rapidly as possible.

61. Atomic Power Plant

If a critical arrangement of material could be produced gradually and controlled, either uranium or plutonium could be used as a continuous source of power. In this case, the number of atoms going through the fissioning process would be held to an amount determined by the rate of energy released desired.

The process has been successfully performed as follows: More than a critical amount of fissionable material is placed in a container. Cadmium rods are set through this material. Some isotopes of cadmium have the property of capturing neutrons without becoming radioactive or unstable, making possible the atomic pile (Fig. 22). In the nonoperating condition, the cadmium rods are fully seated within the critical mass. The cadmium absorbs so many neutrons that a chain reaction cannot be sustained. When it is desired to activate the

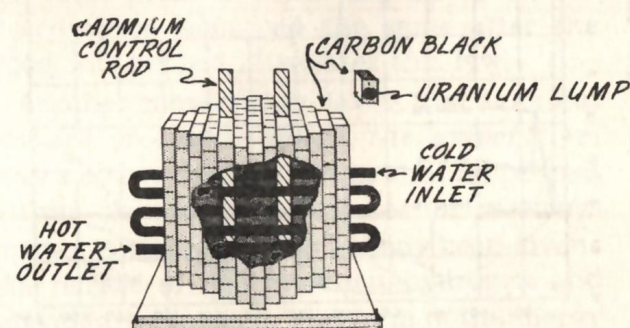


Fig. 22. Schematic drawing of an atomic pile, showing cells, cooling system, and control rods. Arrangement of fissionable material in each cell is indicated in the inset.

atom pile, the cadmium rods are partially removed and fewer neutrons are captured. When the number of neutrons released by fissioning of the material is greater than the number captured by the cadmium, the critical mass sustains a chain reaction and gives off energy. The rate of release of energy is controlled by the cadmium rods. If the rate of fissioning tends to increase, an automatic device inserts the rods farther into the pile, thus absorbing the additional freed neutrons and allowing only a certain number of fissions per unit. As a result, a certain level of energy release is maintained.

SUMMARY

THE ANCIENTS believed that the universe was made up of four elements: earth, air, fire, and water. From the seventeenth century to the nineteenth century an element was thought to be a simple substance that could not be reduced to, or built up from, another substance. An atom was accepted as the smallest unit of an element. By 1869, the Russian scientist Mendeleev had charted the known elements according to their atomic number and chemical properties, leaving blanks in his chart for undiscovered elements. The total was 92. This table, together with an understanding of the nature of compounds, the structure of the molecule, and the laws of conservation of matter and energy, marked the frontier of atomic knowledge in the late nineteenth century. More advanced theories go beyond nineteenth century science but do not refute it.

Beginning in the 1890's, the frontier of knowledge about the atom was rapidly extended. First it was discovered that the atom is not the smallest unit of matter, but that it can be divided into protons (positively charged particles) and electrons (negatively charged particles). These particles give elements their chemical properties. Later it was found that the neutrons added mass to an atom without affecting its chemical properties. At about the same time the phenomenon of radioactivity was observed in certain heavy atoms. As these

atoms radioactively decayed, shooting off alpha particles (helium nuclei consisting of two protons and two neutrons) and beta particles (electrons), they emitted energy in the form of gamma rays. With the loss of energy, as well as particles of mass, the chemical nature of the atoms changed.

In 1905 Einstein advanced his special theory of relativity, which included the proposition that matter could be converted to energy and vice versa. His formula showed that a tiny amount of matter could equal a tremendous amount of energy. The discovery of atomic energy proved this proposition conclusively.

First it was necessary to develop a process by which atoms could be forced to release energy. It was discovered that neutrons and protons have a greater mass within the nucleus of certain heavy atoms than within the nucleus of certain medium-weight atoms. Should one of these heavy atoms split, the protons and neutrons would reduce their mass, and matter would be converted to energy. Moreover, as a heavy atom splits, particles fly out and bombard other such atoms to make them split. A chain reaction is produced if there is present a "critical mass" of fissionable material. Thus was evolved the principle by which atomic energy could be released.

REVIEW QUESTIONS

1. What early experiment illustrated the law of conservation of matter?
2. What kinds of particles constitute an atom? Which are found in the nucleus of the atom? Which in the orbits?
3. Explain the symbol: ${}_{92}\text{U}^{233}$. How many neutrons are implied? What process will this atom go through?
4. What is the approximate difference between the average mass per particle in the nucleus in a heavy atom and the average mass in an atom of medium weight? How is this mass difference used?

Atomic Explosions and Their Effects

THE MOST significant product of the theoretical and technical development discussed in the previous chapter is the atom bomb. We shall now consider that bomb as an Air Force weapon. Like the conventional bombs, guns, rockets, and other weapons discussed in this text, the atom bomb has capabilities and limitations.

In the next chapter we shall discuss some of the operational and logistic problems of atomic warfare, but first we must know something about the bomb itself. As a potential Air Force operations officer, you must understand the atomic explosion itself, the biggest explosion man has ever produced.

An explosion is the sudden release of a large amount of energy in a small space. An atomic explosion differs from an ordinary high-explosive detonation in that a large amount of energy is released from an infinitesimal source. Atomic explosions depend upon a fission process, in which heavy atoms are split into lighter atoms. There is in the process a net loss of mass which appears as energy. For example, the transformation of one gram (1/450 pound) of matter into energy occurs when one kilogram of U-235 or plutonium undergoes fission, and the energy release is the same as for 20,000 tons of TNT. In the detonation of an atomic bomb, approximately 90 percent of the energy is released immediately and 10 percent released later by the radioactive decay of fission fragments. Most of the promptly released energy appears as thermal radiation and blast; the remainder (about 5 percent) appears as nuclear radiation.

The energy released by the atomic bombs exploded over Hiroshima and Nagasaki equalled that obtained by the explosion of

approximately 20,000 tons, or 20 kilotons, of TNT. The energy release of the test bombs at Bikini was about the same. This discussion is concerned with a bomb of that size, usually referred to as a nominal atomic bomb, sometimes called a "20-kiloton TNT energy equivalent bomb," or a "20-KT bomb." Bombs of other energies may be made, and so we use the effects of the nominal atomic bomb as a means of estimating the effects of other atomic bombs.

TYPES OF BURSTS

THE MEDIUM in which a bomb is burst determines to a great extent its various physical effects. The medium may be high above the surface, at the surface, or beneath the surface of land or water.

An *air burst* is the explosion of an atomic weapon in the air, above land or water, or at a height greater than the maximum radius of the fireball. A *surface burst* is the explosion of an atomic weapon at the surface of land or water or at a height less than the maximum fireball radius. An *underground burst* is the explosion of an atomic weapon with its center beneath the surface of the ground. An *underwater burst* is the explosion of an atomic weapon with its center beneath the surface of the water.

62. Air Burst

Upon detonation, an atomic bomb emits a blinding flash of light which immediately becomes a rapidly expanding fireball. The fireball from a 20-KT weapon grows to a radius of 45 feet in 1/10,000 second and consists of gases at approximately 300,000 degrees C. at a pressure of hundreds of thousands of pounds per square inch. During the explosion, the shock front, a "skin" of

highly compressed air, is formed on the surface of the fireball. After .015 second (15 milliseconds) when the fireball radius is about 300 feet, the shock front breaks away from the fireball, which then expands more gradually. The time at which the shock front breaks away is known as the "time of breakaway." After 1 second has elapsed, the fireball reaches its maximum radius of 500 feet, and the shock front has advanced about 2,000 feet ahead of the surface of the fireball. At the time of breakaway, the shock velocity is about 15,000 feet per second. As the pressure in the shock front decreases, the velocity with which it advances also decreases almost to the velocity of sound.

Because of its low relative density, the boiling mass of hot gases making up the fireball rises, attaining a maximum upward velocity of about 300 feet per second (200 miles per hour). The gases expand and cool as they rise, condensing to radioactive smoke which consists of water vapor, metallic oxides from the bomb, and dust drawn up from the ground. The upward motion of the hot mass of gases produces a doughnut shaped cloud, not unlike a smoke ring, which rolls violently as it rises. During the upward motion, the cloud assumes the familiar mushroom appearance. At low altitudes, when the cloud first forms, it is of a brownish color. However, when it reaches high altitudes, water vapor condenses to produce a white cloud. The cloud may reach an altitude of over 40,000 feet before it is gradually dispersed by the winds in the upper atmosphere. Simultaneously with the rise of the fireball, an updraft pulls a tongue of dust from the surface almost up to the fireball, forming a column which often joins the cloud.

The extremely high temperatures in the fireball indicate a considerable loss of energy in thermal radiation, or heat rays. There is sufficient thermal radiation to cause serious burns to exposed persons and to start fires in combustible materials to distances of several thousand yards. Most of the radiation is emitted in about one second.

The nuclear radiation affects only people and animals, leaving equipment and supplies undamaged.

Air Blast. The expansion of the hot gases produced by an atomic explosion causes the formation of a shock wave. This wave, when passing any given point, produces an abrupt rise in pressure, which is followed by a gradual decline to normal, or atmospheric pressure. The pressure continues to decrease gradually to a minimum and then returns to atmospheric. The part of the wave in which the pressure is above atmospheric is the positive phase; the subatmospheric part, the negative phase. The decrease in pressure in the negative phase is always small compared with the increase of pressure in the positive phase. Associated with the pressure changes are mass motions of air or wind. Immediately following the shock wave, a sudden wind of high velocity blows in the direction of shock motion. The wind dies completely and then reverses its course during the negative pressure phase.

The shock wave strikes the surface of the earth and is reflected. This reflected shock wave can produce heavy damage. At a certain point, determined by the height of burst and the energy of the explosion, the direct and reflected shock wave fuse. This fusion phenomenon is called the *mach effect*. In the case of the air burst of a nominal atomic bomb at an altitude of 2,000 feet, the mach effect sets in when the shock front is about 700 yards from ground zero. (Ground zero is the point on the ground directly below the exploding bomb.)

Because of the fusion of the direct and reflected shock waves, the excess pressure in the fused portion, called the *mach wave*, or mach stem, is two to eight times as great as that in the direct shock wave. Consequently, the destructive effect of the explosion may be greatly increased. The greater the distance from ground zero, the greater is the height of the mach wave and the lower the excess pressure, or *overpressure*.

In considering the destruction caused by the shock wave, the important quantity is this overpressure. It is highest at the shock front and falls off toward the region of the

TABLE 7.—CHARACTERISTICS OF THE SHOCK WAVE AT DIFFERENT DISTANCES FROM AN AIR BURST OF A NOMINAL ATOMIC BOMB

Distance from explosion (slant range)	Time of arrival of shock front	Peak overpressure	Wind velocity
yd.	sec.	p.s.i.	m.p.h.
500-----	0.5	25.0	690
1,000-----	1.4	8.0	270
2,000-----	3.8	2.7	96
3,000-----	6.3	1.8	60
4,000-----	9.0	1.5	40

explosion. The maximum pressure at the shock front is called the *peak overpressure*. It is the peak overpressure of the shock wave that largely determines the degree of destruction caused by an atomic explosion in the air.

As the shock front moves outward, the overpressure of the front decreases (Table 7). The destruction effect of the shock wave thus decreases with increasing distance from the bomb. The values of the peak overpressure in the air at various distances from the explosion of a nominal atomic bomb are represented by the third column of Table 7 and by the curve in Fig. 23. The overpres-

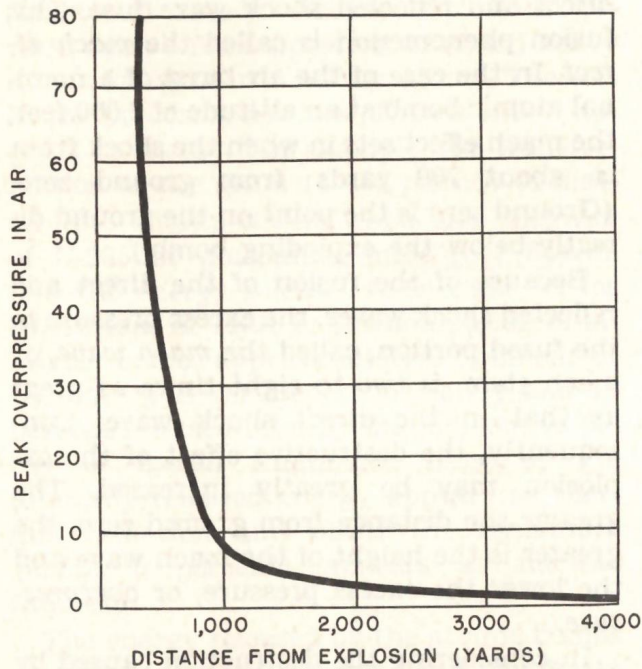


Fig. 23. Peak overpressure varies with the distance from an atomic explosion.

ures are expressed in pounds per square inch (p.s.i.). Normal, or standard, atmospheric pressure at sea level is 14.7 p.s.i. It should be noted that the distances are those from the actual point of burst—that is, the slant ranges—and not from ground zero.

Mach Effect. The mach effect is a particularly important aspect of an air burst because the multiplying effect usually increases with the pressure of the shock wave. For a shock wave of high pressure, the overpressure in the mach wave may be as high as eight times the overpressure in the direct wave. Even for a weak shock, the mach effect may more than double the overpressure. It is evident, then, that the destructiveness of the atomic bomb can be greatly increased by taking advantage of the mach effect.

The overpressure in the direct wave decreases as it moves away from the target, and the mach multiplication decreases correspondingly. Consequently, the advantage gained from the mach effect decreases with distance from the burst.

The height of burst is also an important factor in determining the over-all destruction of an air burst. A low burst, with greater overpressures on the ground, would also have a more greatly multiplied mach effect. On the other hand, a low burst may be wasteful because it results in overdestruction near ground zero.

Calculations have shown that, for a nominal atomic bomb, a burst at a height of 2,000 feet will cause maximum damage on the ground in a modern city. This was roughly the altitude at which the bombs were detonated in the attacks on Hiroshima and Nagasaki. The estimated peak over-

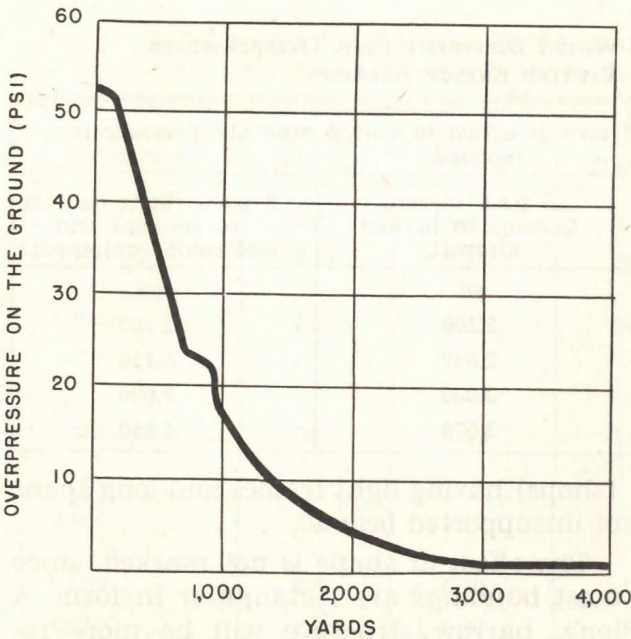


Fig. 24. Peak overpressure on the ground varies with the distance from ground zero when height of burst of a nominal bomb is 2,000 feet.

pressures on the earth's surface at various distances from ground zero, resulting from a nominal atomic bomb exploding at 2,000 feet, are shown in Fig. 24.

The mach effect sets in at about 700 yards from ground zero, where there is a bend in the curve in Fig. 24. In this area the multiplication of pressure through reflection is at its greatest value, a factor of nearly 3. At greater distances from ground zero, the multiplication falls off to a factor of something over 2. At one mile from ground zero in an air blast at an altitude of 2,000 feet, the peak overpressure is roughly 7 p.s.i., as compared with about 3 p.s.i. in the direct shock wave. This difference is significant in determining possible blast damage to buildings.

If the height of burst of the nominal atomic bomb is more than 2,000 feet, the peak overpressures at and near ground zero would be less than that shown in Fig. 24, because of the increased distance from the burst. At a distance of over one-half mile from ground zero, however, the pressures would be a little higher. If the height of the burst was less than 2,000 feet, the reverse would be true: the peak overpressures near ground zero would be greater

than those in Fig. 24, but farther away they would be smaller.

Scaling Law for Bombs of Different Energy Releases. The various data recorded above apply to the explosion of a nominal atomic bomb, or the 20-kiloton TNT energy equivalent. For a bomb having a different energy release, the results can be calculated by the use of a simple rule, often called a scaling law.

In estimating blast effects, the rule is that the distance from the explosion at which any specified overpressure is reached is proportional to the cube root of the energy release. In order to express this rule in terms of distance from ground zero, it is necessary to know the heights of burst used for bombs of different energies. It appears probable that the height of burst which will produce maximum damage on the ground is also proportional to the cube root of the energy release. If this is true, the scaling rule for blast given above will apply to the distance from ground zero, as well as to the distance from the explosion.

If, for a 20-KT bomb, a certain overpressure, say 5.2 p.s.i. is reached at a distance of 2,000 yards from ground zero, then for a W-kiloton TNT energy equivalent bomb the same overpressure will be attained at a distance $(W/20)^{1/3}$ times 2,000 yards. If W is 40, the distance from ground zero would be 2,520 yards; if W is 60, the distance from ground zero would be 2,880 yards. Some damage results calculated in this manner are recorded in Table 8. The distance from ground zero are given at the points where the peak overpressures on the surface are 25, 5, and 3 p.s.i., respectively, for the air burst of bombs of 20-, 40-, 60-, and 100-kiloton TNT energy equivalent. You can see that the distance from ground zero, at which a given pressure is attained and a particular type of destruction is experienced, does not increase in proportion to the energy release of the bomb.

In estimating over-all damage and casualties, however, we must consider the *area* affected by the burst. This is proportional to the two-thirds power of the energy release. Thus, if an air burst of a nominal atomic bomb caused damage, ranging from

TABLE 8.—DISTANCE FROM GROUND ZERO AT WHICH DIFFERENT PEAK OVERPRESSURES ARE REACHED WITH BOMBS OF VARYING ENERGY RELEASES

Energy of bomb in kilotons of TNT	Distance from ground zero at which indicated peak overpressure is reached		
	25 p.s.i. (severe damage to reinforced concrete structures)	5 p.s.i. (severe damage to parked aircraft)	3 p.s.i. (light damage to vehicles and electronic equipment)
	yd.	yd.	yd.
20	700	2,100	2,500
40	880	2,640	3,150
60	1,000	3,030	3,600
100	1,200	3,570	4,250

severe to moderate, to structures over an area of 8 square miles, a 40-kiloton TNT energy equivalent bomb would cause the same damage over an area of (40/20) ²/₃ times 8 (12.7 sq. miles). For a 60-kiloton TNT energy equivalent bomb, damage would extend over (60/20) ²/₃ times 8 (16.6 sq. miles). Doubling the energy release of the bomb increases the area of destruction by about 60 percent; tripling the energy increases the damage area by just over 100 percent.

Blast and Shock Effect on Structures. A structure reacts to a shock or blast wave in air as it would to a giant blow caused by the sudden onset of pressure followed by a comparatively steady force. This continues until the pressure wave reaches the rear of the structure, exerting there a crushing or squeezing effect. Because of the action of these forces, a properly anchored weak structure may be crushed without being displaced bodily. On the other hand, a strong structure may move without being crushed.

The ability of a building to withstand blast depends primarily on its strength and, to a lesser degree, on its shape and on the number of openings that can serve to relieve the pressure on the outside walls. The strength is determined mainly by the type of construction, but this can be modified by various structural details which are not obvious to the eye. The strongest buildings are heavily framed steel and reinforced concrete structures, while the weakest are probably certain shed-type industrial buildings

(shops) having light frames and long spans of unsupported beams.

The effect of shape is not marked, since most buildings are rectangular in form. A long, narrow structure will be more resistant to a blast striking it on the narrow end than on the side. If struck on the side, such a building would probably suffer more damage than one that was nearly square.

The effect of shape is more evident in certain auxiliary parts of structures, such as chords of bridges and smokestacks, than in the main part. Because of the rapid equalization of pressure around them, smokestacks are surprisingly resistant to blast. They often remain standing while adjoining structures are leveled to the ground. On the other hand, flat surfaces at right angle to the blast tend to give way very easily.

The rapid failure of windowpanes, light siding, and other flat, weak portions of a structure is often advantageous. When such failure occurs immediately, there is a tendency for equalization of the pressure inside and outside the building. This reduces the destructive effect of the blast on the structure as a whole.

These effects of air blast apply to explosions of all types. The atomic bomb introduces an additional factor because of its tremendous energy release and the long duration of the blast wave. The blast from an ordinary high-explosive lasts only a few thousandths of a second and affects only parts of a building. The blast wave of an atomic bomb lasts nearly a second and can engulf and damage whole buildings. Fig. 25

TABLE 9.—AIR BLAST DAMAGE PRODUCED AT DIFFERENT DISTANCES FROM GROUND ZERO AFTER THE AIR BURST OF A NOMINAL ATOMIC BOMB AT AN ALTITUDE OF 2,000 FEET (JAPANESE EXPERIENCE)

Distance from ground zero	Wind velocity	Duration of blast	Over-pressure	Type of damage
ft.	m.p.h.	sec.	p.s.i.	
1,000	800	0.37	36.0	Decks of steel plate girder bridge shift laterally
2,000	550	0.45	24.0	Limits of severe structural damage to earthquake-resistant reinforced concrete buildings; reinforced concrete building collapsed, 10-inch walls, 6-inch floor
3,000	380	0.62	16.0	Virtually complete destruction of all buildings, other than reinforced concrete aseismic buildings
4,000	270	0.77	10.0	Reinforced concrete smoke stack with 8-inch walls overturned
5,000	200	0.90	7.4	12-inch brick walls severely cracked
6,000	160	0.98	5.2	Severe damage to entire area; severe structural damage to steel frame building; 9-inch walls moderately cracked
7,000	125	1.06	3.6	Just beyond area of structural damage to multistory brick buildings
8,000	100	1.12	2.9	Severe damage to homes, heavy damage to window frames and doors, foliage scorched by radiant heat
9,000	80	1.15	2.4	Heavy plaster damage
10,000	70	1.20	2.0	Blast damage to majority of homes; severe fire damage expected; flash ignition of dry combustible materials
11,000	60	1.23	1.7	Flash charring of telegraph poles; roof and wall covering on steel frame building damaged
12,000	50	1.25	1.5	Light damage to window frames and doors, moderate plaster damage, complete window damage

shows comparative areas of damage for structures of different types.

Damage Criteria. Table 9 indicates the amount of damage that various overpressures can produce on structures and other materiel. It is based on the effects from a 20-KT atomic bomb such as was used over Hiroshima and Nagasaki in Japan in 1945. The height of detonation was 2,000 feet.

Thermal Radiation. We have estimated the destructiveness of atomic bombs in terms of blast. Now let us consider their withering heat, which makes them both incendiary and explosive weapons.

The instant an atomic bomb explodes, the fireball starts to emit thermal radiation, consisting of ultraviolet, visible, and in-

frared rays. This radiation is actually sent out in two pulses. The first pulse, lasting about 1/100 second, contains a large pro-

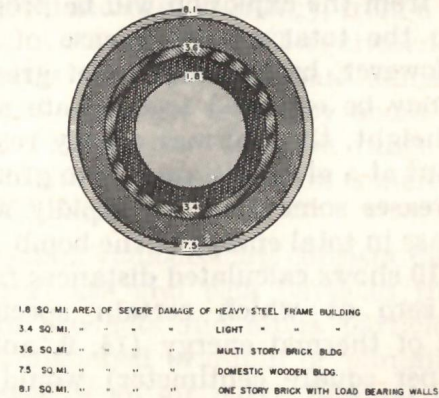


Fig. 25. Comparative areas of damage for different type of structures.

TABLE 10.—DISTANCE FROM GROUND ZERO AT WHICH DIFFERENT AMOUNTS OF THERMAL ENERGY ARE RADIATED BY BOMBS OF VARYING ENERGY RELEASES

Energy of bomb in kilotons of TNT	Distance from ground zero at which indicated thermal radiation is received		
	14 calories per square centimeter (cotton cloth ignites)	9 calories per square centimeter (severe skin burns)	3 calories per square centimeter (moderate skin burns)
	yd.	yd.	yd.
20	1,650	2,150	3,400
40	2,380	2,850	4,300
60	2,750	3,450	5,000
100	3,500	4,100	6,000

portion of ultraviolet light; and the second pulse contains visible radiation, which continues as long as the fireball can be seen, or about 10 seconds. Actually most of the thermal radiation from the atomic explosion takes place within approximately 1 second, and effective emission is over within 3 seconds.

In passing through the air from the explosion to the earth's surface, the thermal radiation is reduced in intensity by molecules in the air and water and the particles of dust and smoke in the atmosphere. Thus thermal damage from an atomic explosion would be less on a hazy or foggy day than on a clear day. Thermal damage decreases as distance from the explosion increases, because of the greater amount of air through which the radiation travels.

It is reasonable to assume that in an atomic explosion the proportion of energy liberated as thermal radiation to total energy released would be approximately the same for bombs of all energies. If this is so, then we can assume that the amount of thermal energy reaching a point at a given distance from the explosion will be proportional to the total energy release of the bomb. However, because bombs of greater energy may be expected to detonate at a greater height, the thermal energy reaching a point at a given distance from ground zero increases somewhat less rapidly with an increase in total energy of the bomb.

Table 10 shows calculated distances from ground zero at which certain specified amounts of thermal energy (14, 9, and 3 calories per square centimeter) would be received on a clear day, as a result of the explosion of bombs of different energy re-

leases. On an exceptionally clear day the respective distances would be somewhat greater, but they would be appreciably less on a foggy day, as noted above. Atmospheric conditions have a more marked effect on small amounts of thermal energy than on large amounts.

You will note that a 20-kiloton TNT energy equivalent bomb produces moderate skin burns at a distance of 3,400 yards from ground zero on a clear day; a 40-kiloton TNT energy equivalent bomb extends the range to 4,300 yards; a 60-kiloton TNT energy equivalent bomb, to 5,000 yards. A threefold increase in the energy release of an atomic bomb would thus increase the range for moderate skin burns by about 40 percent. However, the effective area, which is the important matter from the standpoint of the total number of casualties, is related to the square of the distance. This increase is nearly 60 percent when the bomb energy is doubled, and about 100 percent when it is tripled.

Nuclear Radiation. Blast and heat are two effects of an atomic explosion. A third is nuclear radiation. At the instant of the explosion, gamma rays and neutrons are emitted. In addition, nuclear radiations consisting of gamma rays, beta particles, and alpha particles are expelled by the fission products and by the residual plutonium or uranium in the ball of fire and smoke cloud. Although these radiations continue for some time, only the gamma radiations reach the earth's surface in appreciable amounts during the first minute, with about half arriving in the first second. By the end of a minute the atomic cloud

TABLE 11.—DISTANCE FROM GROUND ZERO AT WHICH DIFFERENT AMOUNTS OF IMMEDIATE NUCLEAR RADIATION ARE RECEIVED FROM BOMBS OF VARYING ENERGY RELEASES

Energy of bomb in kilotons of TNT	Distance from ground zero at which immediate nuclear radiation is received in indicated dosages		
	600 roentgens (LD/100)	450 roentgens (LD/50)	200 roentgens (no deaths expected)
	yd.	yd.	yd.
20	1,190	1,250	1,440
40	1,340	1,410	1,600
60	1,440	1,500	1,700
100	1,550	1,620	1,870

reaches a height of over 2 miles, and nearly all nuclear radiation is absorbed in the intervening air.

It is convenient to consider the nuclear radiation in two parts: (1) the initial, or immediate, and (2) the lingering, or residual.

Immediate nuclear radiation is that reaching the surface of the ground (or sea) from both the ball of fire and the atomic cloud. Hence, it will include the neutrons and gamma rays given off at the instant of the explosion, and the gamma rays emitted by the radioactive products in the rising column of smoke. Although alpha and beta particles are present, we shall not consider them here because they do not reach the earth's surface after an air burst.

Gamma rays are absorbed and hence their intensity is reduced to some extent by the atmosphere. Therefore, the dosage of nuclear radiation received from an atomic air burst decreases as the distance from the explosion increases. It is the general practice to express radiation dosage in terms of a unit called the *roentgen*, a measure of possible injury to personnel.

If a dose of 450 roentgens is received over the whole body within a short period of time, it would prove fatal to about half of the exposed persons. (LD/50 means lethal dose, 50 percent.) However, death is not instantaneous but will occur within 2 to 12 weeks after exposure. The other half of the persons exposed will become sick but will recover. Nearly all persons receiving 600 roentgens over the whole body at one exposure will die within 2 weeks. Those receiving 200 roentgens of gamma radiation

may show no symptoms of illness for 2 or 3 weeks. About half of these persons will eventually become sick, but none is expected to die unless complications develop.

It can be assumed that the energy of the immediate nuclear radiation increases roughly in proportion to the total energy release of the atomic bomb. In this event, the total radiation dosage received at a given point will also be approximately proportional to the energy release. Consequently, for an atomic bomb of W-kilotons TNT energy equivalent, the dosage received at any given distance from ground zero should be multiplied by W/20.

Table 11 shows the approximate distances from ground zero at which 600, 450, and 200 roentgens would be received at an unprotected position from air bursts of different energies. As the energy of the bomb is increased, the effective range for blast and for thermal radiation also increases, but the hazard of immediate nuclear radiation becomes less important. For example, a fivefold increase of energy, from a 20-kiloton to a 100-kiloton TNT equivalent bomb, increases the range of blast damage and thermal radiation injury by about 70 percent; whereas the effective range of the immediate nuclear radiation is increased by only 30 percent.

Residual radioactivity consists mainly of gamma rays and beta particles from the fission products and alpha particles from the unfissioned uranium or plutonium. In the case of an air burst, residual radioactivity is negligible; in surface, underground, and underwater bursts, it is considerable.

63. Surface Burst

A surface burst occurs at the surface or at a height less than the maximum radius of the fireball. The first experimental explosion of an atomic bomb was such a burst. In this experiment, conducted near Alamogordo, New Mexico, on July 16, 1945, the bomb was fixed to a steel tower.

When an atomic bomb is detonated at or near the surface of the earth, it first appears as a sudden, brilliant flash of light similar to that of an air burst. As the ball of fire continues to grow, a shock wave develops in the air. At the same time, pressures amounting to hundreds of thousands of pounds per square inch are exerted on the earth's surface, displacing material to form a crater. In addition to the material thrown out, a considerable quantity of earth is vaporized by the intense heat.

As the ball of fire rises, large amounts of dirt particles are sucked up into the column that produces a mushroom cloud, just as in an air burst. However, in a surface burst, the column and cloud are much more heavily loaded with dirt particles and dust. At Alamogordo the cloud column rose 40,000 feet before spreading out. This height may be considered typical of surface bursts.

Air Blast. The over-all blast effect is less powerful from a surface burst than from an air burst. Part of the energy of the bomb is used up in vaporizing materials on the surface and in forming a crater. Also, up to 15 percent of the energy may go into ground shock. The main point, however, is that because the bomb explodes close to the earth's surface, the overpressure near ground zero is much greater than for an air burst, but it falls off more rapidly with increasing distance. As a result, energy is wasted on targets near ground zero if they are vulnerable to much lower overpressures. At the same time, the overpressures at great distances are too low to cause considerable damage. Stated simply, there is an over-destruction of nearby targets and an under-destruction of those farther away. However, the energy that produces ground shock may destroy or damage underground targets protected from the air blast.

Thermal Radiation. The general characteristics of thermal radiation in a surface explosion are essentially the same as for an air burst. The radiation is emitted from the ball of fire in two pulses: one is immediate and the second occurs in the interval between 1/100 second and 3 seconds after the explosion. The second emission is the chief cause of injury to personnel.

Immediate Nuclear Radiation. The immediate nuclear radiation from a surface burst is similar to that from an air burst. However, it may extend for a slightly longer period because the ball of fire and the radioactive cloud have to travel a greater distance before the gamma rays and neutrons are out of effective range of the earth's surface. For that reason the total dosage of immediate radiations received at a given distance from the surface burst might be greater than from an air burst.

Residual Nuclear Radiation. The residual radiation from a surface burst is much greater than that from an air burst because of the fall-out from the cloud and column. The size of the contaminated area depends upon the meteorological conditions at the time of detonation and, to a lesser degree, upon the character of the soil. In a complete calm, the contamination will form a circular pattern around the point of detonation. If a wind is blowing, there will be an elongated area, varying in shape with the wind pattern.

Fall-Out. The general opinion is that the fall-out after a low air burst might be an inconvenience, but not necessarily an operational hazard. While continuous occupation of the crater region might have to be suspended for a few days, it would be possible to work in the area for short periods within an hour or so after the explosion. At considerable distances from the point of burst there is slight danger from radioactive contamination. However, under certain conditions, such as rain during or soon after the explosion or abnormal air currents, an unusual amount of radioactive material might fall.

64. Underground Burst

When an atomic bomb explodes underground, there is formed a ball of fire made up of a huge bubble of extremely hot, highly compressed gases. The expansion of the gases imparts an outward and upward movement to the surrounding earth. If the explosion occurs at a moderate depth, probably down to 600 feet, the gas bubble will break through to the surface of the earth. At the same time large quantities of earth, rock, and other debris are thrown upward with great force, leaving a crater.

Crater and Column. It is estimated that if a nominal bomb is dropped from the air and penetrates in sandy soil to a depth of 50 feet before exploding, it will produce a crater about 350 feet deep and 400 yards in diameter. This means that an uneven column of over a million tons of contaminated dirt would be hurled from the earth's surface.

Base Surge. When the material from the column falls back to earth, it produces an expanding cloud of fine dust particles. This moves outward from the center of the explosion and is probably carried downwind. Eventually the particles settle, contaminating a large area, the extent of which will depend on the depth of the explosion, the nature of the soil, and the atmospheric conditions.

Fall-Out. The atomic cloud formed in the case of an underground burst contains a very large amount of dirt and debris raised by the violence of the explosion. As a result there will be a considerable fall-out. The larger pieces are first to reach the earth, landing near the center of the explosion. The smaller particles remain in the air for some time and may be carried great distances by the wind before they eventually settle.

Shock Wave. A shock wave in the earth accompanies the rapid expansion of the hot bubble of compressed gas. The effect of this wave is similar to that of an earthquake of moderate intensity, except that the disturbance originates near the surface instead of at great depths. Among other things, this difference in depth means that

the pressures in the shock waves caused by an underground burst fall off more rapidly with distance than do those caused by earthquake waves.

Damage from an underground burst depends on the nature of the soil, on the presence of rock strata which might reflect the shock wave, and on the depth of the burst. Because of these variants, it is impossible to make a satisfactory estimate of damage ranges.

Air Blast. Although the air blast from a subsurface explosion is not so great as that from an air burst, it causes more extensive damage to surface structures than do any other effects of a subsurface burst.

In the case of a burst 50 feet underground, it is believed that about 75 percent of the energy released will not contribute to the ground shock. The distance from ground zero at which a particular peak pressure is observed in an underground burst is about half that for an air burst.

In underground bursts the fireball is obscured by the earth column. Thermal radiation effects are consequently negligible, since nearly all of the thermal radiation is absorbed in fusing and vaporizing the earth.

Immediate Nuclear Radiation. Since the gamma rays and neutrons emitted at the instant of fission are absorbed in a few yards of earth, they are not significant. When the neutrons are absorbed, they may induce within the earth itself an activity which constitutes part of the residual radioactivity.

Residual Nuclear Radiation. It is probable that a base surge of contaminated dust particles will form as the result of an underground explosion. If so, a transit dose will be left on the ground. The relative and actual amounts of these doses depend on various conditions, such as the depth of burst and the nature of the soil. A fairly shallow burst in soft or sandy soil, for example, will probably be accompanied by a considerable base surge of high activity.

As far as radioactive contamination is concerned, however, the situation is not so bad as might be expected. This is because of the rapid decay of the fission products, especially in the early stages. The longer a

contaminated particle remains suspended before falling, the less active it is on the ground. For that reason, particles falling some distance from the burst are in the air for a relatively long time and are consequently reduced in activity. It is to be expected that, after an underground explosion, radioactive contamination will be a serious hazard only in and near the crater region.

According to estimates, one hour after the explosion of a nominal bomb, the radiation dose rate within one-half mile of surface zero will be about 2,000 roentgens per hour, making the explosion area uninhabitable for some time.

65. Underwater Burst

The phenomena accompanying an underwater burst depend on the depth and area of the body of water, on the distance below the surface at which the detonation occurs, and on the energy release of the bomb. In Test Baker at Bikini, a 20-kiloton TNT energy equivalent bomb was detonated at a depth greater than 50 feet below the surface of the lagoon, which was about 200 feet deep.

As in an air burst, in an underwater burst there is formed a ball of fire, consisting of a huge bubble of extremely hot, highly compressed gases. The rapid expansion of these gases produces a shock wave in the water similar to that accompanying an air burst. The shock wave, however, travels much faster in water than in air.

If the depth of burst is moderate, the ball of fire remains essentially intact until it comes to the surface. At this point the pressure in the giant bubble is released and, as a result of a complex series of phenomena, the water is thrown up with great force in a hollow, chimney-like cylinder of spray. At the same time a shock or blast wave is sent out through the surrounding air.

The maximum height attained by the column at Bikini, before it began to fall back, was probably over 6,000 feet, the top being hidden by the atomic cloud. The column was about 2,000 feet across, and the thickness of the walls was estimated at ap-

proximately 300 feet. At least a million tons of water rose in this cylinder of spray. It included material that had been sucked from the bottom of the lagoon by the force of the explosion.

The contents of the gas bubble were vented through the top of the giant chimney to form the atomic cloud. This cloud resembled a cauliflower in shape, being roughly spherical with a diameter of some 6,000 feet. Its maximum height of 8,000 feet is considerably less than that of the atomic cloud in an air burst.

After the underwater explosion at Bikini, the water fell back from the column to the surface of the lagoon, forming a cloud of mist called the base surge. This ring-shaped cloud, billowing upward, rapidly attained a vertical development of over 900 feet, and moved outward at an initial rate of more than a mile a minute. The radius of the cloud grew, at first rapidly and then more slowly, to nearly 3,000 yards in 4 minutes, while the vertical development increased to about 1,800 feet. At this stage the bottom of the base surge appeared to rise from the surface of the water and to merge with clouds in the sky.

Water Shock. Because of the difference in the physical nature of water and air, the peak overpressures attained by the shock wave are much higher in water than in air. The normal speed of sound in water is about a mile a second, and the initial speed of the shock wave is several times greater. On the other hand, the pressure falls off fairly rapidly as distance from the explosion increases.

Qualitative data are insufficient to determine peak overpressures and degree of damage from underwater shock. However, it is more likely that damage caused by air shock and water waves will exceed that caused by underwater shock.

Air Blast. If an underwater burst took place at great depth, the gas bubble might well break up and lose its identity in a mass of turbulent water below the surface. In this case there would be no column of water and spray and, consequently, no base surge. Similarly, an atomic explosion

underwater in a shallow harbor might produce no true water column. However, because of the lack of precise knowledge about the formation of the base surge, we must be prepared for defense against it.

Water Waves. The disturbance created by the underwater burst at Bikini caused a series of waves to radiate from the center of the explosion across the surface of the lagoon. Eleven seconds after the explosion, the first wave reached a maximum height of 94 feet at about 340 yards from surface zero. This wave moved outward at high speed, followed by a succession of waves of decreasing height.

Thermal Radiation. Thermal radiation is completely absorbed in vaporizing the surrounding water. It produces no direct effect.

Immediate Nuclear Radiation. In the air burst, it is possible to distinguish between the immediate nuclear radiation and any residual radioactivity, because the gamma rays, neutrons, and beta particles from the ball of fire, as well as the atomic cloud, are out of range of the earth in about a minute. But in a subsurface burst, no such sharp distinction is possible. However, it is known that the gamma rays and neutrons emitted in the actual fission process are unimportant in an underwater burst. Passage through a few yards of water reduces these radiations to such an extent that they are harmless.

Residual Nuclear Radiation. The base surge is highly radioactive as it contains most of the fission products in the water of the column. Except for its radioactivity, which represents a serious hazard, the base surge would be nothing more than an interesting phenomenon.

The radiation dosage received from the base surge may be accounted for in two ways. The radioactive cloud exposes to radiation any area over which it passes, during the time that it is in transit. This provides the *transit dose*. In addition, some of the contaminated water falls as rain from the base surge, leading to the deposit of radioactive material on surfaces. The resulting radiation dosage may be re-

ferred to as the *deposit dose*, or contamination dose. The transit dose thus resembles immediate radiation, while the deposit dose arises from residual radioactivity.

Fall-Out. In addition to the effect of the base surge, radioactive contamination results from the particles carried down by the fall-out of masses of water from the column and the cauliflower cloud. Partly because of the great weight of the water thrown into the air by the explosion, and partly because of the low temperature, the cloud does not reach the heights observed in an air burst. Hence, the fall-out begins very soon after the explosion. It was noticeable within a minute at Bikini; thus, a large part of the radioactive fission products was quickly deposited within a radius of a few thousand yards from surface zero. Hazards of residual radioactivity from an underwater burst in a city area are estimated in Fig. 26.

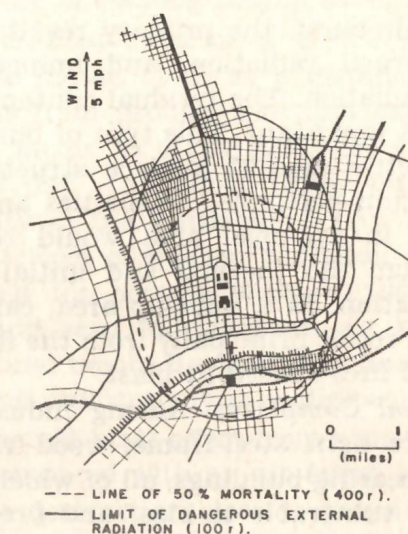


Fig. 26. Hypothetical city showing approximate limit of residual radiation dosages from an underwater burst.

SELECTION OF BURST

THE COMMANDER or staff officer in the field will have to face the problem of selecting the type of burst to suit the target. Since different types of bursts produce varying degrees of damage, the relative magnitude of the damage produced by each must be the principal basis of comparison. It is not

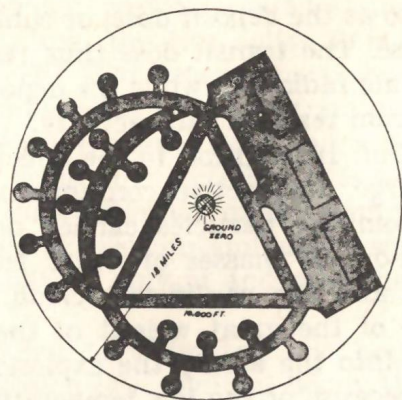


Fig. 27. Effect of an aerial burst of an atomic bomb on an airport.

possible to ascribe a simple scale of damage potential to each type of bursts, because within each type the damage varies. However, these generalizations about the effects of different bursts on various targets may be helpful.

66. Targets for Air Burst

In an air burst, the primary results are blast, thermal radiation, and immediate nuclear radiation. The residual contamination is less important. This type of burst is most effective against surface structures, materiel, and personnel. Casualties among personnel in an open area would result chiefly from the thermal and initial nuclear radiation. In a built-up area, casualties would result principally from the flying debris and fires caused by blast.

Industrial Complexes. Among industrial targets are light steel-frame, wood-frame, and wall-bearing buildings, all of which are extremely vulnerable to blast and fire. Industrial equipment, such as machine tools, motors, and generators, are resistant to blast but will be damaged by falling debris and fires. A 20-KT atomic bomb detonated at 2,000 feet over an industrial area would result in severe blast damage to a radius of 4,500 feet.

Troop Concentrations. Concentrations of troops are vulnerable to thermal and nuclear radiation of an air burst. Vulnerability depends on the degree of concentration and on the types of protection provided the personnel.

In Europe during World War II and later in Korea, an entire division would occupy an area no larger than 3,000 yards square. Employment of a 20-KT air burst atomic bomb against such a concentration would result in approximately 90 percent casualties.

Foxholes afford personnel good protection when the range is greater than one-half mile. Bunkers afford almost complete protection. It is not feasible that troops will always be protected by foxholes and bunkers, particularly at newly established airheads and beachheads.

Airfields. An airfield is generally considered an extremely vulnerable target (Fig. 27). Light steel-frame and wooden buildings would be severely damaged to ranges greater than 1½ miles. Aircraft would be damaged to a radius of one mile. In addition to the material damage, a high percentage of casualties would result.

67. Targets for Surface Burst

The surface burst produces maximum destruction in the immediate vicinity of the point of detonation. In addition, there would be considerable residual contamination near ground zero. This type of burst is particularly effective against massive structures and airfield runways.

Massive Structures. The surface burst provides high overpressures necessary to destroy massive, reinforced concrete structures.

Airfield Runways. Airfield runways are vulnerable to cratering and ground shock from a surface burst. The radius of damage to runways would depend upon the type of soil surrounding the runway.

68. Targets for Subsurface Burst

The primary effects of the subsurface burst are ground shock, cratering, and ground contamination. This type of burst causes extensive damage to underground structures and leaves heavy deposits of residual contamination. The same general effects can be expected from underwater bursts in terms of water shock, wave action, and fall-out.

Submarine Pens. Submarine pens are bombproof structures of heavily reinforced concrete which would not be extensively damaged by air or surface burst. Destruction is possible with a subsurface burst, chiefly through ground and water shock (Fig. 28).

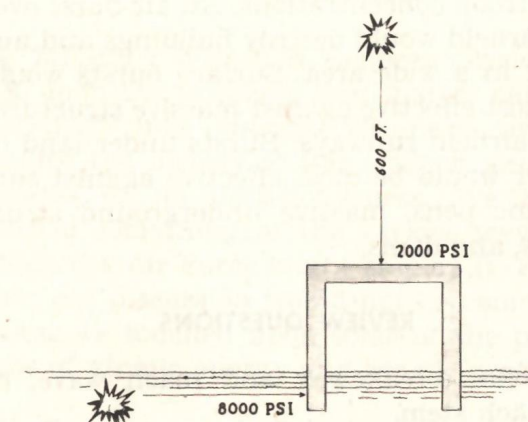


Fig. 28. Effect of penetrating atomic bomb on submarine pen.

Reservoir Dams. Dams in general are not vulnerable to an air or surface burst, but they could probably be destroyed by a subsurface burst, chiefly through ground and water shock.

Massive Underground Structures. Underground structures are invulnerable to air blasts. However, a subsurface burst could probably destroy this type of structure through cratering and ground shock.

SUMMARY

A LITTLE MORE than two pounds of U-235 or plutonium, undergoing fission and converting but one gram (one thousandth) of its mass into energy, will produce an explosion equalling that of 40 million pounds of TNT. The Hiroshima and Nagasaki bombs and the test bombs exploded at Bikini were all approximately 20-KT bombs, or nominal atomic bombs. Effects of bombs of other energies can be scaled to the nominal bomb.

The atomic bomb is not an indiscriminately destructive weapon that can decide a war simply by being detonated behind the enemy lines. Markedly varying effects de-

pend upon whether atomic weapons are exploded above, on, or below the surface.

Air bursts most clearly demonstrate the essential effects of all atomic bombs: blast, heat, and nuclear radiation. The air burst is defined as an explosion occurring in the air at a height greater than the maximum radius of the fireball. Air blast from a 20-KT bomb produces pressures of 25 p.s.i. over atmospheric, enough to collapse a reinforced concrete building at a distance of 700 yards from ground zero. This scaling rule can be used for bombs of other than nominal energies: The distance from either the point of detonation or from ground zero at which a certain overpressure is experienced is in proportion to the cube root of the energy release; and the area over which a given overpressure is spread is in proportion to the two-thirds power of the energy release. This is true of conventional as well as atomic bombs, but the atomic bomb is proportionately more destructive because of its long-lasting blast wave.

The heat rays of a 20-KT bomb can ignite cotton cloth at a distance of 1,650 yards from ground zero and cause severe skin burns at 2,150 yards on an average clear day (this effect varies with the humidity in the atmosphere). An immediate lethal dose of nuclear radiation can be expected for persons within 1,190 yards of ground zero following an air burst of a nominal bomb. However, the hazard of lingering radioactivity is negligible.

The net blast effect from a surface burst, as compared with an air burst, is more intense destruction close to ground zero but less destruction farther out. The force of a surface burst will actually produce a crater beneath the point of detonation and lift great masses of dust and debris into the air. Although air shock produced by a surface burst will fall off more sharply with distance than is the case in an air burst, earth shock may damage underground structures that are invulnerable to an air burst. Thermal and immediate radiation effects are similar to those of an air burst, and there is the added hazard of lingering, or

residual, radioactivity in the crater and in falling dust and debris.

Effects of an underground burst would vary according to the depth of the explosion and the nature of the soil. It has been estimated that a nominal bomb detonated at a depth of 50 feet in sandy soil would produce a crater 350 feet deep and 400 yards in diameter. Damage effects due to earth shock beyond this area would vary greatly and are hard to estimate. The radius for a given air blast effect produced by such an underground burst would be half that for the same effect from an air burst of the same weapon. Thermal rays passing through the air would be negligible because most of the heat would be used up in fusing and vaporizing the earth immediately around the point of detonation. Residual radioactivity, however, would be very strong—part of it induced in the ground itself and part of it present in the falling dust and debris that form an expanding cloud near the surface.

Pictures of the underwater burst at Bikini show the characteristic giant chimney of spray screening the fireball and the great cauliflower-shaped cloud loaded with radioactive moisture. With moisture, as with dirt in an underground explosion, the radioactive fall-out would present serious hazards. There would also be a heavy, rapidly transmitted water shock, considerable air blast, and water waves large enough to engulf the shores surrounding a harbor or lagoon area.

In general the air burst, with its maximum air blast and thermal and initial radiation effects, is the most widely devastating and lethal use of an atomic bomb. However, its residual radiation effects are at a minimum, and it would be relatively ineffective against underground targets. It could be employed against industrial areas and troop concentrations. An air burst over an airfield would destroy buildings and aircraft in a wide area. Surface bursts would be most effective against massive structures and airfield runways. Bursts under land or water would be most effective against submarine pens, massive underground structures, and dams.

REVIEW QUESTIONS

1. Define breakaway and mach wave, or mach stem.
2. What would be the effect of an air burst of a 40-kiloton bomb on a steel-frame building 2,600 yards from ground zero?
3. Would it be safe to enter the radioactive area immediately around surface zero one hour after detonation of a nominal atomic bomb in the air? on the surface? underground? underwater?
4. What is base surge? With what types of bursts is it associated?
5. In case of withdrawal, it would be advantageous to deny the enemy access to the evacuated areas. What would limit our use of atomic weapons to contaminate those areas?

Problems of Atomic Warfare

A MIGHTY WEAPON has been developed upon the principle that matter can be converted into energy. We have briefly studied the history of this weapon and estimates of its destructiveness. We have learned something of the various ways in which the Air Force might employ it. However, our discussion would not be complete unless we touched upon some of the problems of atomic energy and atomic warfare.

69. The Economic Problem

Underlying many other problems is the problem of the scarcity of atomic materials and the costliness of atomic weapons.

In a way, this scarcity is a paradox. The formula $E = Mc^2$ means that potential atomic energy exists in all matter in inconceivable strength. Theoretically, this is true. Theoretically, there is enough atomic energy in the shoes on your feet to destroy hundreds of Hiroshimas.

But science has not yet discovered how to release the atomic energy locked up in commonplace matter. So far, scientists have been able to release a very small part of the atomic energy of certain rare substances, and only after these substances have been put through costly, elaborate, and slow refining processes. Consequently, building and maintaining an atomic arsenal put a severe strain on the mightiest nations. Every American taxpayer has felt this strain. Mr. David Lilienthal, the first chairman of the Atomic Energy Commission, once stated that each atomic bomb costs approximately one million dollars. More advanced weapons may cost as much as five million dollars each.

Cost in dollars does not tell the whole story. It merely reflects the doctrine of

scarcity which at present governs the production and use of atomic energy. The weapons and materiel of World War II were costly, too, but at the end of the war we had more munitions, planes, vehicles, and various kind of equipment than we had at the beginning. Our production was exceeding our consumption. Such is not the case with atomic energy. Known sources of supply and present methods of production put definite limits upon atomic energy. Under wartime conditions it could be used up faster than it could be produced.

Since we live in a time of national peril, the bulk of our fissionable material is going into atomic bombs. Each bomb that is detonated, whether in a peacetime test or on a military target, irretrievably expends a part of our fissionable material. Furthermore, the use of fissionable materials for peaceful purposes, or for such military purposes as radiological warfare or nuclear-powered airplanes and submarines, means fewer atomic bombs. All projected uses of atomic power must be considered in the light of military necessity. Consequently, there can be little or no flexibility in setting priorities.

It is true that in a few years the sources of fissionable material will be expended unless new findings of uranium or new processes for refining ores of low concentration extend the supply. This does not mean that we will run out of atomic bombs several years from now; it simply means that all available raw materials will have been refined and built into atomic weapons. Once the uranium is refined it will last indefinitely unless it is expended. The half life of U^{235} is 891 million years, and the half life of plutonium is 24,000 years. There is

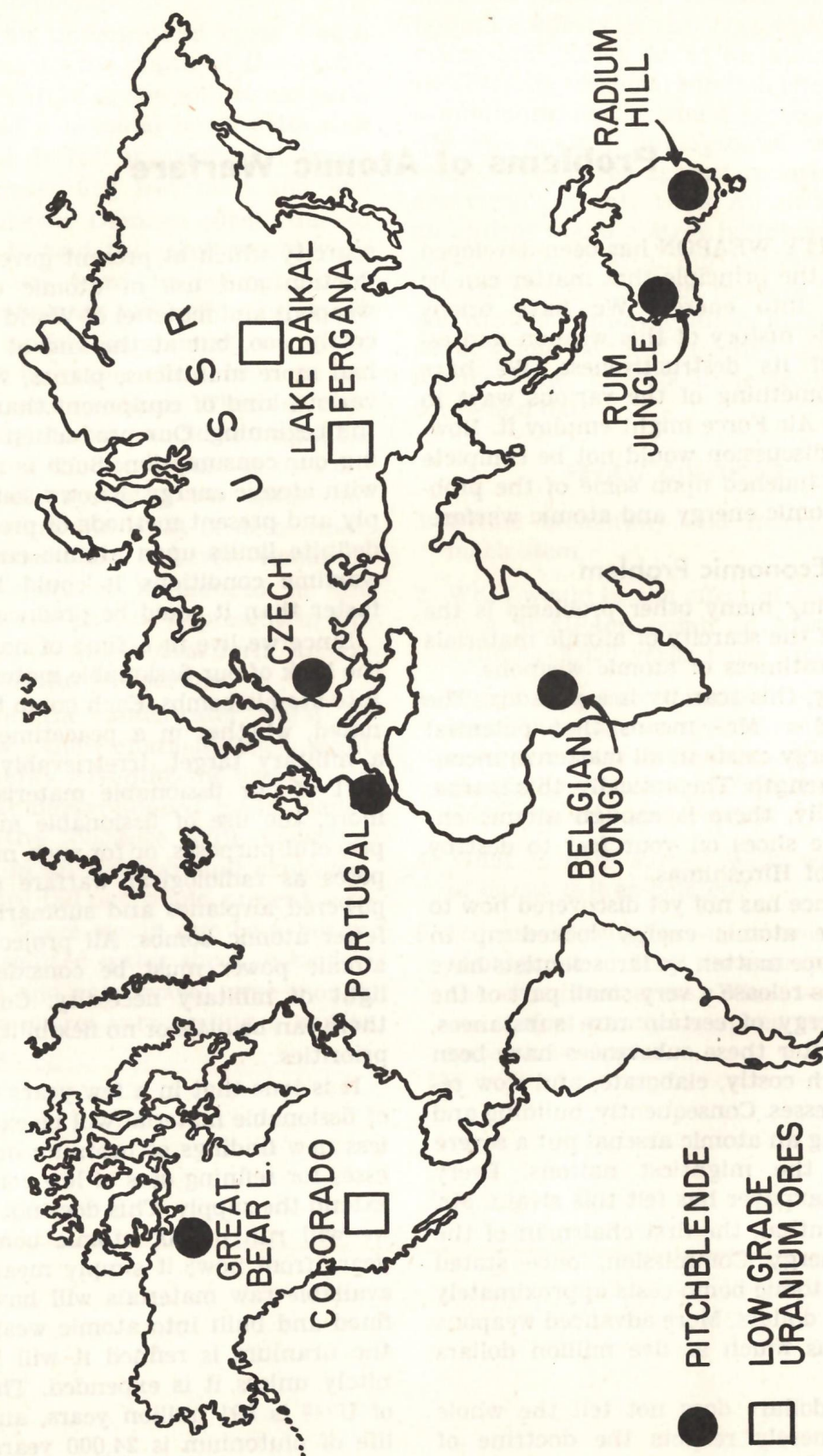


Fig. 29. Map showing sources of uranium.

their suspicion Germany was attempting to build one. By then the Germans had occupied Czechoslovakia and had stopped the export of uranium ores. The conclusion was that they intended to use the ores to build the atomic bomb.

President Roosevelt immediately set up the Advisory Committee on Uranium to look into the matter and to make recommendations. By mid-1942, the Manhattan Engineer District (MED) was organized for always the possibility that the fissionable material now made into atomic bombs can be reworked and put to other uses.

Let us look more closely at this problem. At present there are two fissionable materials employed in the atomic energy program: uranium found in nature and plutonium produced in atomic piles or reactors. Since plutonium is produced from uranium, the supply of both materials depends upon the amount of uranium ore found in the earth's crust. Both of these materials can be used in an atomic bomb or as a source of power for an atomic engine.

Uranium is neither scarce nor new. It was used in industry many years before the development of atomic energy, and it is more plentiful than gold or silver. There is this difficulty: uranium is so widely diffused through the earth's crust that it does not occur in sufficient concentrations or degrees of purity to be refined economically.

There are at present several sources of uranium available to the United States (Fig. 29). Among them are (1) the Shinkolobwe deposits in the Belgium Congo, (2) the Colorado Plateau area, including parts of Colorado, New Mexico, Arizona, and Utah, (3) the Great Bear Lake region in northern Canada, (4) Lake Athabaska, south of Great Bear Lake, (5) the Rum Jungle, in the northern territory of Australia, and (6) Johannesburg, South Africa, where uranium might be reclaimed from gold mines. (As yet undeveloped, the Lake Athabaska and Johannesburg sources are being investigated as future possibilities.)

Our doctrine of scarcity applies, however, not so much to the availability of uranium

ores as to the facilities available for separating U^{235} and U^{238} and for producing Pu^{239} . As it exists in nature, uranium is found in three isotopic forms, U^{234} , U^{235} , and U^{238} , but only 1 part in 140 is in the fissionable form of U^{235} . The amount of U^{234} present is negligible (1/200,000). The main task is the separation of U^{235} from U^{238} and the production of Pu^{239} . One of the functions of the Oak Ridge complex is to separate U^{235} from U^{238} , while at Hanford, Washington, uranium is placed in reactors and plutonium is produced.

As new methods are developed and as new facilities are built for the separation of U^{235} from U^{238} and for the production of plutonium, the doctrine of scarcity will have less meaning than it has today.

70. Joint Civilian and Military Control

In this text we consider atomic bombs, along with 20-mm. bullets, as Air Force weapons. It is true that the bulk of the U.S. atomic arsenal is designed for Air Force delivery. Yet with an understanding of the immense power of these weapons and of their present cost and critical scarcity, we realize that these factors present a huge and complex problem of control for any nation possessing the resource of atomic energy. It is a responsibility far too great for the Air Force to cope with alone. Apparently it is beyond exclusive military control. This point may be debatable, but it represents official U.S. Government policy at present.

Prior to World War II, scientists of many nations frequently exchanged ideas and compared notes on potential scientific developments. At the outbreak of war, some of these scientists had concluded that it was possible to obtain energy from the atom. In October 1939, shortly after the fall of Poland, a refugee scientist, Alexander Sachs, presented himself to President Roosevelt with a letter of introduction from Dr. Albert Einstein. Sachs informed the President of the opinion among scientists that the atomic bomb could be built and of the purpose of building the atomic bomb.

Within a few months Major General Leslie Groves of the Army was appointed to the command of that organization, a position he held until 1946. The Manhattan Engineer District was successful in building the atomic bomb in slightly less than three years. A grand total of 2 billion dollars went into the project.

Being a military organization commanded by an Army general, the Manhattan Engineer District handled its supply and administrative procedures in a military manner.

Atomic Energy Commission. After the war ended, our nation looked forward to a long period of peace. It was felt that there was no future need for atomic weapons and that a new type of organization was needed to handle atomic energy matters. With the Atomic Energy Act of 1946 (Public Law 585), the 79th Congress set up the Atomic Energy Commission (AEC) to see that atomic energy would be used to improve public welfare, increase the standard of living, strengthen free enterprise, and promote world peace. In contrast with the Manhattan Engineer District, the Atomic Energy Commission is a civilian organization whose chairman is appointed by the President. Its primary functions are (1) to build and stockpile atomic bombs, (2) to conduct atomic research, (3) to control all fissionable material, (4) to take over and hold all atomic patents, and (5) to control all information about atomic energy.

The seven program divisions of the Atomic Energy Commission are (1) Raw Materials, (2) Biology and Medicine, (3) Reactor Development, (4) Production, (5) Research, (6) Engineering, and (7) Military Application.

Although the Commission was set up primarily to exploit atomic energy for civilian uses, to date only about 1 percent of our fissionable material has been used for civilian purposes and about 99 percent for making atomic weapons.

The Atomic Energy Commission has a complex organization (Fig. 30). Its principal link with the armed forces is provided by the Santa Fe Office of Operations

through the Sandia Corporation, which is located at Sandia Base, New Mexico, and which works very closely with the Field Command, Armed Forces Special Weapons Project, and the Air Force Special Weapons Center, located at Kirtland Air Force Base, New Mexico.

Joint Congressional Committee. The Atomic Energy Commission, however, is only part of a complex of military and civilian agencies involved in atomic energy (Fig. 31). At the time the Atomic Energy Commission was set up, a Joint Congressional Committee was established as a watchdog committee. Of the nine Senators and nine Representatives making up this committee, not more than five from each house of Congress can represent one political party. It is the responsibility of the committee to study the activities of the Atomic Energy Commission pertaining to development, use, and control of atomic energy, and to handle all bills and resolutions on atomic energy for Congress.

General Advisory Committee. The General Advisory Committee is made up of nine American scientists who have no direct connection with the Atomic Energy Commission. The intent is to provide an additional panel of experts on whose knowledge and experience the Commission can draw. The General Advisory Committee meets four times a year to advise the Commission on scientific and technical matters relating to production of atomic material.

Military Liaison Committee (MLC). At the same time that the Atomic Energy Commission was established, Congress provided for a Military Liaison Committee between the Department of Defense and the Atomic Energy Commission. This committee gives the military a voice in the expenditure of fissionable material, in the location of bomb stockpiles, and in the trends to be followed in research and development. The Military Liaison Committee sees that the acts of the Atomic Energy Commission do not conflict with the responsibilities of the Department of Defense and keeps the Commission informed on activities of the Department of Defense that pertain to atomic energy. Ap-

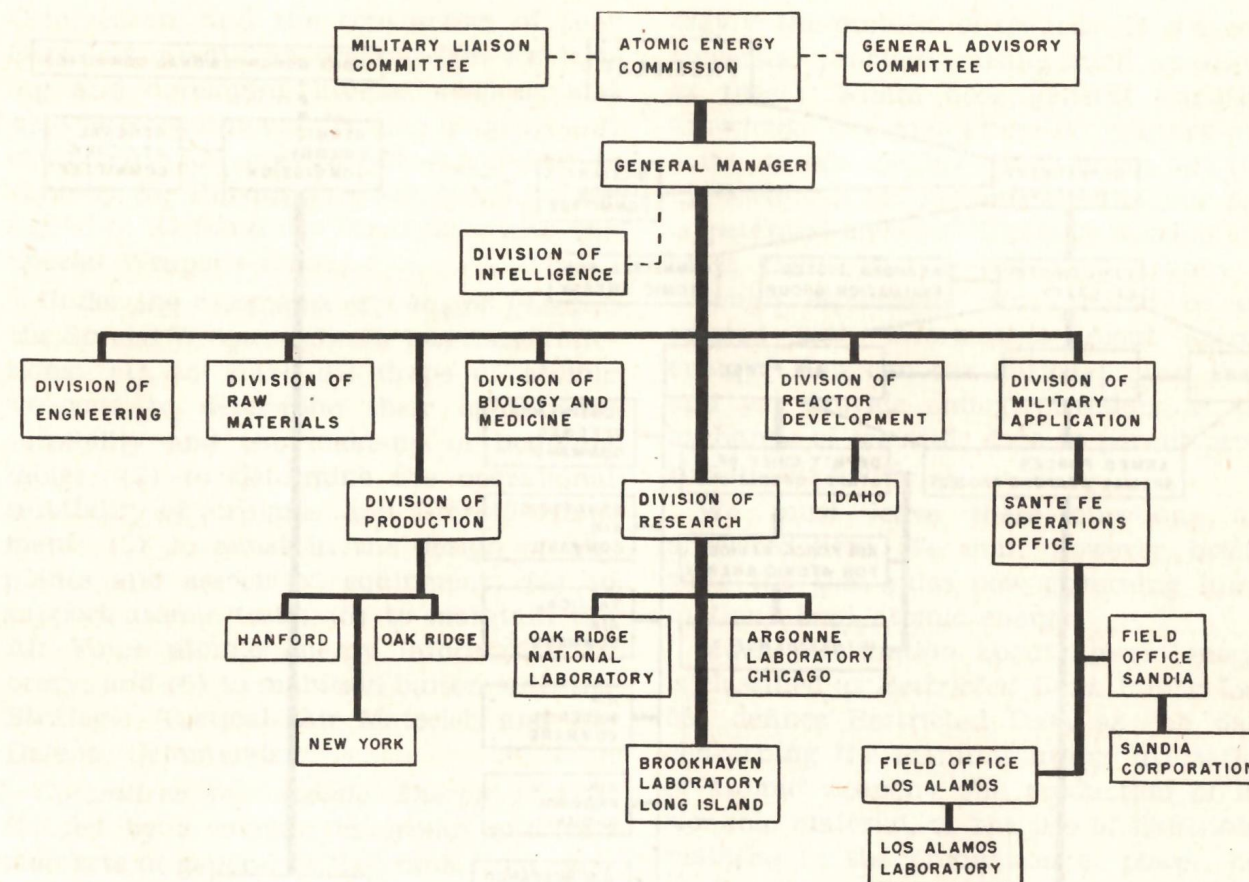


Fig. 30. Organization of the Atomic Energy Commission.

pointed by the President, the civilian chairman of the Military Liaison Committee may also serve as Deputy for Atomic Energy Matters to the Secretary of Defense. The committee is composed of two members from each of the three services, all of general or flag rank.

Armed Forces Special Weapons Project (AFSWP). Established in January 1947, the Armed Forces Special Weapons Project took over the remaining military functions of the Manhattan Engineer District. Its functions are (1) to provide technical training of special personnel, (2) to participate in the development of atomic weapons and equipment, (3) to coordinate the requirements of the three services and their budgets for atomic tests, (4) to support the war plans as drawn up for the Joint Chiefs of Staff, and (5) to act for the Department of Defense in contacting civilian agencies.

The headquarters of this agency is located in the Pentagon. Its field command, located at Sandia Base, provides technical

training and monitors logistic matters.

The Armed Forces Special Weapons Project is made up of personnel of the three services and, at present, is headed by an Air Force general with deputies from the Army and Navy. The project does not come directly under the Joint Chiefs of Staff, but is under the individual Chiefs of Staff of the Air Force and of the Army and the Chief of Naval Operations.

Air Force Office for Atomic Energy (AFOAT). Immediately after World War II, the Air Force did not go all out to develop a capability for atomic delivery. By 1947 war was probable. It was then that the Air Force Office for Atomic Energy was organized to monitor all atomic energy activities for the entire Air Staff. At the time there were few Air Force personnel with the required technical know-how and extremely few with the necessary clearances. Some of the cleared officers who were competent in this field were assigned to the Air Force Office for Atomic Energy until officers in

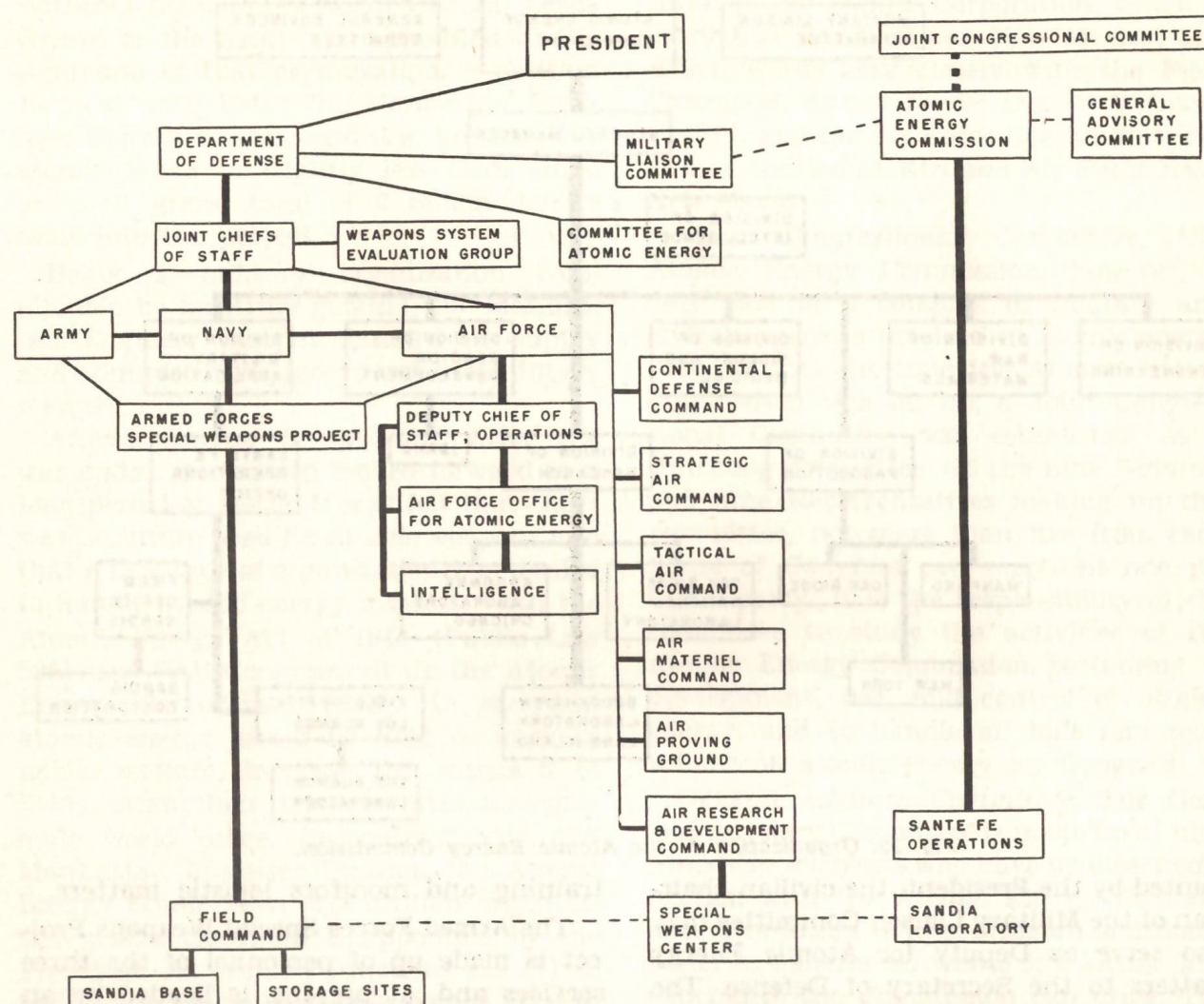


Fig. 31. Principal organizations for atomic energy.

other Air Force activities could be cleared and trained.

The functions of the Air Force Office for Atomic Energy are as follows: (1) to review war plans in the light of atomic problems; (2) to evaluate maneuvers, exercises, and tests of atomic energy; (3) to coordinate operational requirements; (4) to advise on atomic energy programming and security policies; (5) to monitor on the Air Staff all Air Force atomic energy technical activities; (6) to monitor on the Air Staff all Air Force atomic energy supply, maintenance, and logistic activities; and (7) to provide technical assistance to members of the Air Force, the Military Liaison Committee, and the Committee for Atomic Energy (see below).

The Air Force Office for Atomic Energy was originally set up as a coordinating office with an Atomic Energy Division, but it has since been expanded to include Chemical Warfare and Biological Warfare Divisions. It is headed by the Assistant Deputy Chief of Staff of Operations for Atomic Energy.

Special Weapons Center. When the Air Force Office for Atomic Energy was first set up, its field office at Kirtland Air Force Base was called the Tactical and Technical Committee. Soon it became the Field Office for Atomic Energy and then the Special Weapons Command. Currently known as the Special Weapons Center of the Air Research and Development Command, it provides the Air Force, the Atomic Energy

Commission, and the contractors of that Commission with an organization for testing and developing atomic weapons and associated equipment. Testing weapons and equipment for operational suitability is done by Air Proving Ground personnel assigned to Kirtland Air Force Base with the Special Weapons Center.

Under the command of a major general, the Special Weapons Center has these functions: (1) to make air drops of atomic weapons to determine their operational suitability and the make-up of bombing tables; (2) to determine the operational suitability of airplanes and aircraft equipment; (3) to assist in the design of airplanes and associated equipment; (4) to support atomic tests; (5) to maintain the Air Force atomic energy information library; and (6) to maintain liaison with the Strategic, Tactical, Air Materiel, and Air Defense Commands.

Committee for Atomic Energy (CAE). Headed by a civilian chairman and two members of general or flag rank from each of the three services, the Committee for Atomic Energy performs within the field of atomic energy the same functions that the Research and Development Board performs in all areas of research and development. The Committee for Atomic Energy allocates among the services those functions pertaining to atomic energy research and development, and it monitors and assigns specific research projects.

Weapons System Evaluation Group (WSEG). This group was set up in December 1948 to evaluate weapons systems for all the services and to recommend the best types of weapons systems for future use. It provides rigorous, unprejudiced, and independent analysis and evaluation of present and future weapons systems under possible combat conditions. Its directives come from both the Joint Chiefs of Staff and the Research and Development Board.

71. Security

Closely related to the problem of joint civilian and military control of atomic en-

ergy is the problem of security. It is a controversial problem, raising such questions as these: Where does general scientific knowledge end and where do military and state secrets begin? How much of this knowledge is in the possession of our real or potential enemies? Did they develop any of it themselves or did they acquire it through espionage? Who should be entrusted with information about atomic energy? How can our nation protect itself and yet provide enough freedom in the exchange of scientific data to permit progress in this field?

We must leave these questions unanswered here. We shall, however, briefly state the U.S. rules now governing information about atomic energy.

Much information about atomic energy is classified as *Restricted Data*. Public Law 585 defines Restricted Data as "all data concerning the manufacture or utilization of atomic weapons, the production of fissionable material, or the use of fissionable material in the production of power, but shall not include any data which the Commission from time to time determines may be published without adversely affecting the common defense and security." This means simply that all information about atomic energy is Restricted Data except what the Atomic Energy Commission has specifically declassified.

There is no direct relationship between Restricted Data and the military classifications of Top Secret, Secret, and Confidential. A document that is declared Restricted Data by the Atomic Energy Commission can carry any military classification, depending on the safeguards desired by the military.

Prior to February 1951, personnel within the Department of Defense having access to Restricted Data had to be cleared for atomic energy information. A clearance of this nature was given by the Federal Bureau of Investigation or the Office of Special Investigations. Since February 1951, however, a Restricted Data clearance, as such, is no longer required for military or civilian personnel within the Department

of Defense. Instead there are now two requirements: (1) A "need to know" must exist. Personnel will have access to Restricted Data only if they need this information in the performance of their work. (2) They must have a military clearance to see Restricted Data which also carry a military security classification. For example, personnel within the Department of Defense who are cleared for military Secret material may have access to Restricted Data which carry a military classification of Secret or less. If they have a Top Secret clearance, they may have access to Restricted Data carrying the military classification of Top Secret or less.

Civilian personnel outside the Department of Defense must be cleared by the Federal Bureau of Investigation in order to use Restricted Data.

Personnel within the Department of Defense who must deal with the Atomic Energy Commission or its contractors must also be investigated and cleared by the Federal Bureau of Investigation. A military Top Secret clearance is not sufficient for such duties, although it allows persons access to Restricted Data, provided they get it from any source other than the Atomic Energy Commission or its contractors.

Public Law 585 provides in part that anyone having an intent to injure the United States or give an advantage to a foreign nation through the use of Restricted Data, and who (a) acquires, or attempts or conspires to acquire, anything involving Restricted Data, or (b) removes, conceals, or tampers with anything involving Restricted Data, or (c) having lawful or unlawful possession of, or access to, anything involving Restricted Data, discloses, or attempts or conspires to disclose, such data to anyone, shall be punished by law. In addition, anyone involved in (c) above may also be punished by law though no intent as stated above is present, if he has reason to believe the Restricted Data may be used to the injury of the United States, or to the advantage of a foreign nation.

72. Logistics of Atomic Warfare

To return now to the use of atomic energy as a weapon, let us examine some of the logistic problems that lie behind atomic warfare.

The power of one atomic bomb and one delivery aircraft together represent a World War II striking force of thousands of bombs and hundreds of aircraft. This basic concept of the power of one bomb and one aircraft could very easily lead us to think that the logistic problems of atomic warfare have decreased; actually they have increased. Why? Because support for one atomic bomb and its great destructive potential demands logistic planning and the constant readiness of an assembly capability anywhere on earth. This task is complicated by the fact that atomic warfare would probably involve launching attacks on many targets at one time from many points of the globe. Thus logistic planning has been stretched beyond the point reached during World War II.

History of Logistic Support for Atomic Warfare. During the fall of 1948 the first specialized depot under the command of the Armed Forces Special Weapons Project was activated to provide all logistic support for atomic special weapons assembly organizations. The policy then was that organizations trained and activated for this purpose were to remain at Sandia Base. Here a pool of technicians was maintained to assist in atomic operations conducted by any of the three services. This concept was sound in those early days because then there were enough technicians in the pool in proportion to the atomic bombs in our stockpile.

Sandia Special Weapons Depot received, stored, and issued all atomic training materiel for the three services. It dealt directly with the contractors of the Atomic Energy Commission in the procurement of atomic materiel. It prepared and controlled the program that listed materiel needs for all three services. It allocated this materiel in accordance with agreements between the Armed Forces Special Weapons Project and the three services. The Army, Navy, and Air Force each received atomic training bombs,

test equipment, specialized materiel handling equipment, and spares. There were enough supplies to maintain standards of operational efficiency in line with the assembly capabilities that the Joint Chiefs of Staff had established for each service.

In mid-1949, operational concepts began to change; the assembly organizations stationed at Sandia Base under the command of the Armed Forces Special Weapons Project were transferred to their respective services. Air Force assembly organizations were assigned to certain strategic bombardment wings. At this point it became clear that it took more than the usual time for the logistic support provided by Sandia Special Weapons Depot to get through the pipeline from the manufacturer to the forward bases. The Air Force recognized the problem and arrived at this solution: The Air Materiel Command was authorized to plan for specialized depots that would make it easier to get logistic support to Air Force special weapons assembly organizations.

About two years later (July 1, 1951) the first Air Force specialized depot was activated at Kirtland Air Force Base to provide support of special weapons assembly organizations operating in the field with Air Force operational units. An agreement between the Atomic Energy Commission, Armed Forces Special Weapons Project, and the Air Force authorized the Air Force to receive a fixed percentage of materiel procured by the Atomic Energy Commission.

Shortly after the activation of the first specialized depot, an Air Force expansion program got underway. Additional specialized depots were planned and activated for world-wide logistic support of new special weapons units being trained and certified for operation in the field.

Limitations on Atomic Logistics. The basic principles of logistics have not changed in the actual training, moving, and supplying of men and bases. However, atomic logistics has assumed new aspects because of three limiting factors:

1. Low stock-control level of certain atomic materiel. Atomic materiel is in short supply, as explained earlier. Because the

source of fissionable materials for the atomic bomb is limited, there is a limit on not only the number of atomic bombs that we can build but also on the stock-control levels of certain atomic materiel. This second limitation exists because the budget and program are based upon the shortage of resources. For example, during part of a fiscal year a major item, such as a piece of equipment used in testing a component of an atomic bomb, would be manufactured in very small quantities. Thus, each piece of equipment in production would have an allocation "name tag" put on it before the specialized depot received it. The "tag" would state which Air Force organization is to get the equipment. Multiply this procedure by hundreds of items and you will understand why the stock-control level is extremely low. It is evident that the limitation on materiel does not apply only to the source of fissionable products but also to the material used in the mechanical and electrical components of the weapons system.

2. Economic limitations. There is also the economic limitation on atomic logistics discussed earlier in this chapter. We can assume that our stockpile of atomic bombs will have reached its highest level the day we start expending them for warfare. Because of the time lag in production, we could quickly expend more bombs than we could replace. We can measure the cost of atomic production, but we cannot assign each bomb a value in dollars and cents because it represents a definite portion of our national security.

3. Need for quality control. To insure that the atomic bomb reaches the highest possible reliability, we must have the best technology and the finest resources. In maintaining quality, specifications must be stated in thousandths of a second and thousandths of an inch. For men handling atomic materiel, we demand exacting training known heretofore only to a few scientists. All this is to insure that the best possible end product is obtained for the money and resources expended.

Air Force Supply Procedures. In accordance with the joint agreement between the Atomic Energy Commission, the Armed Forces Special Weapons Project, and the Air Force, the Air Materiel Command determines and submits to the Armed Forces Special Weapons Project all Air Force requirements for atomic materiel to be supplied by the Atomic Energy Commission. The Project then consolidates the Air Force requirements with those of the other two services. This procedure keeps the program unified and complies with the agreement that only the Armed Forces Special Weapons Project is to deal with the Atomic Energy Commission for the procurement of material from its prime contractors, the Sandia Corporation and the Los Alamos Scientific Laboratories.

Materiel earmarked for the Air Force is controlled by the Materiel Control Branch of the Field Command, Armed Forces Special Weapons Project, which monitors allocation for all three services. However, to reduce the cost of transportation between manufacturer and user, atomic materiel for the Air Force is now being delivered direct from the contractor of the Atomic Energy Commission to the Air Force specialized depots. Sandia Special Weapons Depot has been eliminated from the supply pipeline.

In accordance with the Air Force supply system, all atomic and peculiar materiel is listed under the classification 39-D.

Training in Atomic Logistics. To provide logistic support for the assembly of atomic bombs and for the use of specialized equipment needed in this program, personnel must be given highly specialized training along lines previously limited to scientists and a very small number of military personnel. One of the prime missions of the Armed Forces Special Weapons Project is to operate as the atomic technical training center for the three services.

Before being chosen for this highly specialized training, each man is thoroughly screened and evaluated as a security risk. He is also screened for his other qualifications. If he is accepted, he is transferred to the Armed Forces Special Weapons

Project at Sandia Base. Here he takes a comprehensive training course on the atomic bomb and its related equipment. During and after training, each man is further evaluated as a security risk. Only after the findings are satisfactory is he integrated into one of the special weapons assembly organizations. The man is then "certified" as being qualified to carry out a certain part of the logistic mission. He fits into the logistic pattern of a precise and comprehensive plan drawn up by the Joint Chiefs of Staff.

The utmost care is used in screening and training personnel for special weapons assembly organizations because a single mistake could have tremendous significance. It might very well cause an atomic bomb to fail at the target. The repercussions from such a failure might be compared with what would have happened during World War II if an entire numbered air force had been sabotaged.

Planning for Atomic Logistics. To sum up, never before in the history of Air Force logistics in peacetime has it been necessary to plan so continuously and so completely on a wartime basis as it is necessary to do when atomic materiel is to be used. The planner must, in fact, build up capabilities for logistic support with such precision that if the decision is made to release atomic energy for wartime use, the logistics organizations in the field will immediately do their job with absolute efficiency. A lesser degree of efficiency is not acceptable. Further, the logistics and operations staffs must coordinate completely if the operation is to be successful.

Throughout the phases of logistics planning, the stock levels of atomic materiel must be precisely controlled. Because of the limitations noted, stock levels must be constantly reviewed and adjustments made within the Air Force program. Further, stock control must conform to joint agreements between the Air Force, the Atomic Energy Commission, and the Armed Forces Special Weapons Project, if materiel is to get to the right organizations at the right time.

73. Special Operational Problems of Atomic Warfare

In addition to the logistic problems, certain operational problems must be solved when atomic weapons are used.

First, the selection of the type of burst is a highly important operational problem. In the previous chapter we learned that the effects produced by an atomic bomb depend upon whether it is exploded above, on, or beneath the surface of land or water.

There are other operational problems that are also important, all because of the fact that each atomic bomb represents a considerable portion of our chances for success in a war. To put it more strongly, each atomic bomb strengthens our chances for national survival and for the preservation of our way of life. This fact puts a heavy responsibility upon atomic technicians, supply men, and the men who deliver the weapon.

Crews and Equipment for Delivering Atomic Bombs. Each crew selected for the purpose should be even more carefully screened and trained than our lead crews were during World War II. The men should be given the best equipment available. Suppose, for example, that it takes N number of bombs to knock out a target system. Suppose further that, with the present quality of our crews and equipment, the circular probable error is F feet. If, by a more careful selection and more intensified training of crews and a continued improvement of equipment, the circular probable error could be reduced from F feet to $F/2$ feet, then approximately half of N bombs could accomplish the mission. This example, though somewhat oversimplified, takes on real meaning when we consider the limits of our atomic stockpile. Whereas increased accuracy in bombing does not actually add to the atomic stockpile, it does increase the damage each atomic bomb can produce.

Reconnaissance for Atomic Warfare. The atomic bomb has also made an impact on reconnaissance for air warfare. In World War II, reconnaissance aircraft took pic-

tures of potential targets. Usually these aircraft were unmolested, because the enemy knew that one airplane could bring about little destruction. After a mass attack on a target, reconnaissance crews returned to photograph the damage, once more practically ignored.

In an atomic war in which great distances might have to be spanned, the functions of reconnaissance are greatly increased at the same time that reconnaissance aircraft are exposed to greater danger. In general, if we are to use atomic bombs, we would need good photos of the target area for visual bombing and radarscope photos for radar bombing. In addition, our atomic bomb crews must have as much information as possible about the check points along the route to the target. The reconnaissance units will be responsible for getting this information, and they can expect serious opposition every time they venture within range of enemy defenses. A B-50 carrying an atomic bomb and an RB-50 look the same, both visually and on the radarscope, and they will undoubtedly get the same reaction from the enemy. Once the bomb is dropped, the reconnaissance units may be required to get photos of the damage. In this way it is likely that reconnaissance aircraft will fly two missions to the bomber's one. They may go out before the bomber takes off for the mission and again after the bomb has been dropped.

Just as the atomic bomb has increased the importance of the reconnaissance unit, so has it greatly increased the need for better equipment for navigation, communications, and bombing.

Target Selection for Atomic Bombs. Of all phases of preparation for atomic warfare, target selection has probably increased in importance more than any other. During World War II, the Army Air Forces dropped bombs on targets of widely different types. Both oil refineries and aircraft plants were bombed in Germany. Actually, had we succeeded in knocking out the oil refineries, there would have been little need for attacking aircraft plants, but we

bombed both because we felt that we had an unlimited supply of bombs.

With the atomic bomb, unlike conventional bombs, we must select only those targets whose destruction will contribute to our victory.

The question often arises as to whether the atomic bomb should be used against personnel or against installations. Since only a few people in Hiroshima and Nagasaki were in bomb shelters when the atomic drops were made, the death toll was high, but the figures are misleading. Such concentration of personnel in a target area is very unlikely in any future atomic operation. Although the atomic bomb is perhaps the most effective antipersonnel weapon yet devised, it is generally believed that it could be used more tellingly against installations than against personnel.

The atomic bomb has greatly emphasized the time factor in warfare. Our aim is to drop bombs more quickly and heavily than the enemy can. To accomplish our aim, we must have an air force in being. Before hostilities begin, airplanes should be in tactical units, completely equipped for war. Crews should be trained and ready. We should maintain complete logistic preparedness. All plans must be made, targets and routes to targets selected, and tactics devised. In short, all organizations directly involved must be ready to carry out their mission.

Tactics for Atomic Warfare. Also of importance are the tactics to be used in delivering the atomic bomb. In devising tactics, we should strive for greater safety in delivery and, at the same time, greater bombing accuracy. These two do not usually go hand in hand. Each bomb must be delivered safely because of its great value to the nation; each must be dropped accurately because only then can it contribute its part toward victory. By flying faster and higher, the aircraft carrying the bomb gains in safety but loses in bombing accuracy. Greater protection from enemy defenses is possible by attacking in bad weather or during darkness, but this advantage is offset by the fact that visual

bombing is more accurate than radar bombing. In determining the safety of the crew, bomb, and airplane as against the factor of bombing accuracy, compromises must be made.

The detonation of an atomic bomb produces three significant effects: blast, heat, and nuclear radiation, as explained in Chapter 6. These can seriously affect aircraft and crews delivering the bomb. An aircraft is primarily affected by blast and heat. Nuclear radiation cannot cause engine malfunction or destroy an airframe, but if the aircraft flies through an atomic cloud and picks up fission fragments, the aircraft must be decontaminated.

The crew is more seriously affected by heat and nuclear radiation than by blast. A pressure of several hundred pounds per square inch would crush a man, but death would first result from thermal or nuclear radiation.

The amounts of blast and heat an aircraft can withstand are major factors in determining the minimum altitude at which a safe drop can be made without damage to the aircraft. This altitude can be lowered if the aircraft, immediately after bomb release, executes a turn and flies away from the detonation point.

The blast necessary to bring down an aircraft is indicated by an overpressure figure measured in pounds per square inch. Generally, a fighter-type aircraft should be capable of sustaining greater overpressures than a bomber type because the fighter type is constructed more ruggedly.

Since the amount of thermal radiation varies in intensity with atmospheric conditions in the immediate area, visibility is important in determining the altitude for the drop. If visibility is good, thermal radiation will usually be the primary limiting factor because it is emitted instantaneously.

To be safe from excessive overpressure, a bomber-type aircraft dropping a nominal bomb should, at the time of release, be 9,000 feet above the known detonation altitude. However, visibility should not exceed 20 miles; otherwise, thermal radiation be-

comes the limiting factor. If a breakaway maneuver is used, the minimum release altitude could be lowered to 7,500 feet, but in this instance the visibility could be no greater than 6 miles.

The fighter-type aircraft could release from lower altitudes, but in extreme cases where visibility is exceptionally poor, nuclear radiation becomes the limiting factor if the same crew members participate in subsequent missions during a relatively short time.

Because of scaling laws, the minimum safe altitudes of release do not increase in direct proportion to the size of the bomb. In other words, if a 40-kiloton weapon could be employed, the minimum release altitude above the detonation point would not be twice that for the 20-kiloton bomb (or 18,000 feet for a bomber at a visibility of 20 miles or less), but rather 11,500 feet.

At altitudes where an aircraft may be safe from the thermal effects of an atomic burst, its crew members may receive second- or third-degree skin burns. In night operations at any altitude, anyone who looks directly at the area of explosion during the fireball phase may suffer temporary blindness. Crew members must remember to protect their skin from exposure and to control their curiosity.

The radioactive cloud from an atomic explosion rises 30,000 feet in five minutes, by which time its radius is 5,300 feet. If an aircraft is traveling at the rate of 300 miles per hour, it can go through the thickest part of the cloud in 24 seconds. During this time the crew would be exposed to 71 roentgens. No crew member should die or suffer radiation sickness from this dosage. Only at altitudes of 25,000 feet or less would there be enough contamination to cause serious radiation sickness. At 15,000 feet, the radioactivity would be sufficiently intense to cause the death of 50 percent of the crew. These figures are based on the 20-KT bomb.

If weapons of larger yield could be employed, the increase in radiation effects would be directly proportional to the increase in time necessary to traverse the larger cloud. Furthermore, an additional

hazard would exist because of the larger amount of acquired radioactivity of the aircraft. Should fission fragments enter the interior of the aircraft through an induction system, they would be extremely hazardous to crew members. For the remainder of the flight, crew members would therefore refrain from eating and smoking and would wear oxygen masks. Crews exposed to considerable dosages of radioactivity would have to be taken off missions which might expose them to further contamination.

The Atomic Bomb Compared With Conventional Bombs. Finally, we shall compare the damaging effects of the atomic bomb with those of conventional bombs, considering only the number of airplanes employed. One big airplane carrying a 20-KT bomb carries in it as much explosive force as 2,000 airplanes, each carrying a load of 20,000 pounds. However, the airplane carrying the 20-KT bomb carries less destruction than the 2,000 airplanes. This is so because the explosion of the atomic bomb is more localized. Because the point directly under the bomb is overdestroyed, energy is wasted. Actually, it would take only 200 airplanes, each carrying 20,000 pounds of bombs, to produce damage equal to that of 20-KT atomic bomb. It was estimated that 200 aircraft carrying 20,000 pounds of conventional bombs each could have damaged Hiroshima to the same degree as did the atomic bomb. Hiroshima had not been bombed prior to the atomic attack. Nagasaki had been bombed only slightly by B-29's. These cities were purposely spared to determine the exact effect of the atomic bomb. Thus we had a good basis for estimating the number of conventional aircraft that could do the same job.

People in responsible positions are not maintaining that the atomic bomb alone could win a war. What they are saying is that, if the atomic bomb is properly employed, it might win a *decision*. By this statement they mean that the atomic bomb could make it plain that we would win the war if it could destroy the enemy's economy before he could destroy ours. Once such destruction were brought about, the ex-

ploitation phase of the war could then be fought with conventional land, sea, and air forces.

74. Research and Development

To this point in our discussion, we have emphasized the 20-KT, or nominal, atomic bomb. Here let us mention some possible developments in atomic weapons and atomic energy.

New Fission Bombs. The Atomic Energy Commission is conducting research to find ways to increase the yield of atomic bombs. It is hoped that this increase can be brought about by rearranging the ratios and positions of the nuclear components. The purpose is to get either more yield or more bombs without using additional fissionable material. The Pacific tests of 1948 and 1951 indicated that we then had bombs more powerful than those detonated over Hiroshima and Nagasaki. The Nevada tests of 1951, 1952, and 1953 showed further proof of development. In fact, it is difficult to incorporate improvements into our stockpile of atomic bombs because several developments in research are always being made simultaneously in different places. For this reason we are slow in adding each development to the stockpile, and all the great improvements made in atomic energy since the end of World War II are not reflected in the stockpile. It is expected that future atomic bombs will vary widely in size and yield from the present bombs.

Nuclear-Powered Aircraft. With the development of the atomic bomb it became apparent that the energy released from the fission process could be harnessed and controlled. In 1946 the Air Force began studies on the feasibility of developing an aircraft powered by nuclear energy. The project, known as ANP (Aircraft Nuclear Propulsion), has been progressing steadily. The success of the project depends upon a satisfactory solution to these problems: (1) Materials will have to be developed that can withstand higher temperatures than those previously known in conventional engines. (2) Some kind of shielding will have to be put on the aircraft to protect the crew from

radiation. This shielding must be made of such material and it must be so placed that it does not add too much to the gross weight of the aircraft. (3) Several methods for collecting the heat from the nuclear reactor and for delivering it to the power plant will have to be investigated to discover the best method. (4) Bases will have to be constructed for test flying, and special facilities must be provided for handling the weapons on the ground.

Two well-known firms, together with the Air Force, the Atomic Energy Commission, and the National Advisory Committee on Aeronautics, are solving these problems. Much of the project still centers around basic research and the development of parts. It is too early to predict when a nuclear-powered aircraft will fly. An artist's conception of such an aircraft is shown in Fig. 32.

Theoretically, a nuclear-powered aircraft could carry within it an almost inexhaustible source of energy. Since it would not have to refuel, its range would be unlimited. The tactical advantage of having a nuclear-powered fast-flying heavy bomber that could travel at either high or low altitudes is obvious. If such a bomber, with a cruise speed as high as 460 knots, traveled along lat. 57° N., it could follow the earth's daily revolutions. In this way the aircraft could remain in darkness. Even on June 21, when the midnight sun is at its brightest, there would still be enough darkness at altitudes as low as 50,000 feet to hide the aircraft.

Nuclear-Powered Submarines. While the Air Force is developing a mobile reactor for nuclear-powered aircraft, the Navy is working on nuclear-powered submarines (Project NEPS). Although the basic principles of both projects are similar, the weight of the nuclear reactor in a submarine or surface vessel presents fewer difficulties than in an aircraft.

The Electric Boat Company is building the hull for the first nuclear-powered submarine, and General Electric is developing the reactor at Schenectady, New York.

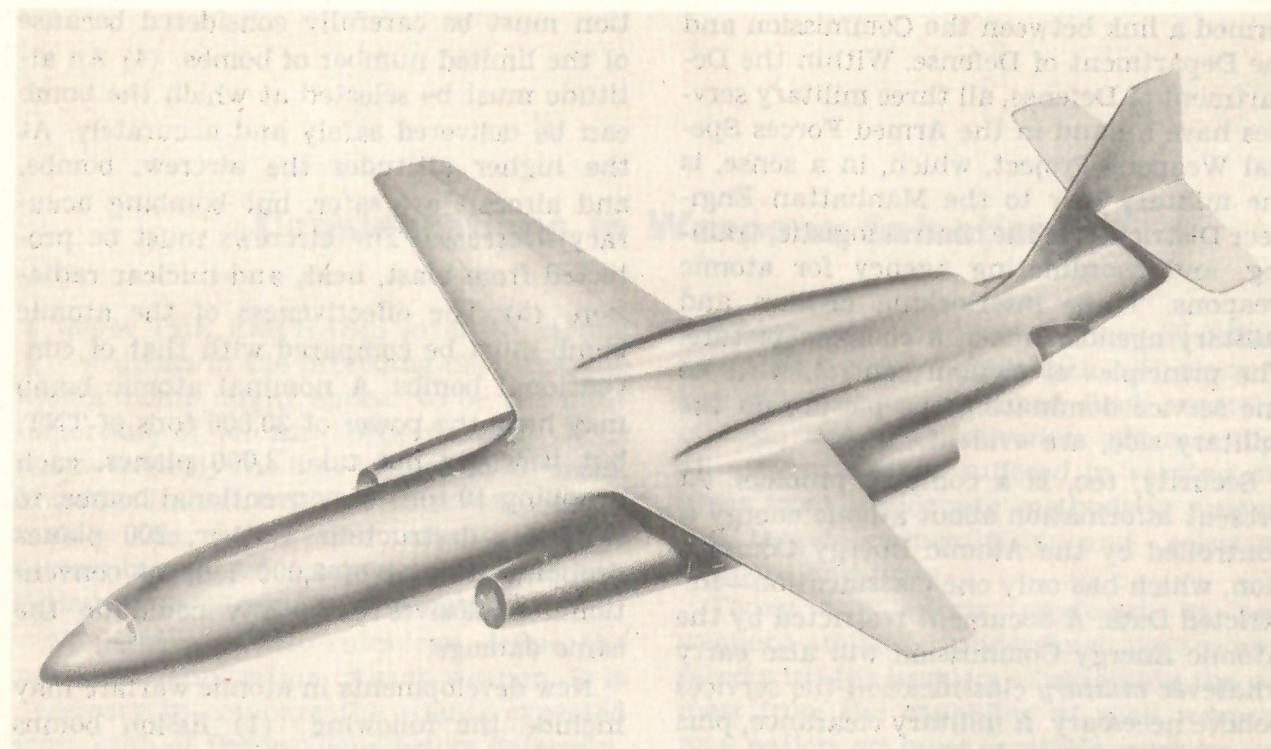


Fig. 32. Artist's conception of a nuclear-powered aircraft.

It is expected that nuclear-powered submarines will be operational before nuclear-powered aircraft.

Breeding Process. The Atomic Energy Commission believes that a nuclear reactor can be built that will breed more atomic fuel than it consumes. This reactor could use natural uranium. Natural uranium could be made to yield about 140 times as much energy if the U^{238} atoms are used in addition to the U^{235} atoms.

When natural uranium (mostly U^{238}) is put in the atomic pile, the U^{235} atom, a minor component, starts splitting. During the process, energy, fission products, and free neutrons are released. Part of the neutrons are needed to split more U^{235} and keep the reaction going; others are absorbed by impurities or escape from the pile; the rest enter the atoms of U^{238} and convert them into plutonium. If the breeding process proves feasible, it would reduce the waste of fissionable material and cause more neutrons to be absorbed by the U^{238} . If the amount of plutonium produced exceeds the amount of U^{235} consumed, we have more nuclear fuel than at the beginning.

SUMMARY

IN THIS CHAPTER we have discussed a number of problems related to the production and employment of atomic energy and atomic weapons.

The doctrine of scarcity presents a fundamental problem. There are limited natural sources of uranium, the essential raw material for all forms of atomic energy known to science today. The process of refining this material into a form that yields atomic energy is infinitely costly, elaborate, and slow. During wartime, atomic energy could be used up faster than it could be produced.

The immense power of atomic weapons, coupled with their astronomical cost and critical scarcity, presents a tremendous and complex problem of control. Our nation has felt that this control should not be exclusively military. The Manhattan Engineer District, which developed the first atomic bombs during World War II, was a military organization, but in 1946 Congress set up both the civilian Atomic Energy Commission as the central controlling agency and a joint Congressional committee as a "watchdog." A Military Liaison Committee

formed a link between the Commission and the Department of Defense. Within the Department of Defense, all three military services have a hand in the Armed Forces Special Weapons Project, which, in a sense, is the military heir to the Manhattan Engineer District. It is the central logistic, training, and coordinating agency for atomic weapons. These interlocking civilian and military agencies make a complex picture. The principles of civilian control, with no one service dominating the picture on the military side, are evident.

Security, too, is a complex problem. At present information about atomic energy is controlled by the Atomic Energy Commission, which has only one classification—Restricted Data. A document restricted by the Atomic Energy Commission will also carry whatever *military* classification the services believe necessary. A military clearance, plus an established “need to know,” is necessary before a military or civilian member of the Department of Defense can gain access to Restricted Data of the Atomic Energy Commission.

Logistic requirements for atomic weapons are especially heavy. For safety and for the sake of making every precious bomb count, the system must function with 100-percent efficiency. Through the Air Materiel Command, the Sandia Special Weapons Depot receives, stores, and issues all materials for atomic weapons. Each service has its own units of specialists who assemble atomic weapons. All men working with atomic logistics must be selected with the utmost care and trained with complete thoroughness. Rigid procedures for stock control of components for atomic weapons are necessary if these components are to be ready for assembly at locations scattered all over the world.

Besides burst selection, which was discussed in the previous chapter, atomic warfare involves these operational problems: (1) The crews that deliver atomic bombs must be trained more rigorously to make every bomb count. (2) There must be two hazardous reconnaissance missions for every bombing mission. (3) Target selec-

tion must be carefully considered because of the limited number of bombs. (4) An altitude must be selected at which the bomb can be delivered safely and accurately. At the higher altitudes the aircrew, bombs, and aircraft are safer, but bombing accuracy decreases. The aircrews must be protected from blast, heat, and nuclear radiation. (5) The effectiveness of the atomic bomb must be compared with that of conventional bombs. A nominal atomic bomb may have the power of 20,000 tons of TNT, but it would not take 2,000 planes, each dropping 10 tons of conventional bombs, to equal its destruction. Rather, 200 planes dropping a total of 2,000 tons of conventional explosives on a city could do the same damage.

New developments in atomic warfare may include the following: (1) fission bombs more powerful than the nominal bombs, or more bombs from the same amount of fissionable material; (2) a nuclear-powered aircraft; and (3) a nuclear-powered submarine. Other new developments may include a breeding process whereby expended U^{235} increases the supply of fissionable material. The atomic power plant has already functioned in experimental tests.

REVIEW QUESTIONS

1. How does the doctrine of scarcity affect the development of atomic energy for peaceful uses?
2. What are the links between the Atomic Energy Commission and the military agencies using atomic weapons?
3. Why are the logistics problems of atomic warfare greater than those of warfare with conventional weapons?
4. Why should reconnaissance missions in atomic warfare be more hazardous than those of World War II?
5. How does visibility affect the safe-release altitude for an aircraft dropping an atomic bomb?

Considerations in Weapons Selection

FROM THE EMPHASIS given to atomic weapons in the preceding chapters, the atomic bomb might appear to be the most important of all Air Force weapons. It is not necessarily the best weapon in all cases, however. Indeed, while no other weapon can match the devastating effects of the atomic bomb, each weapon and fuze is best suited for a particular application.

No hard and fast rules can define the particular application of each weapon. It is necessary to compare the results expected from each of the weapons before determining the best weapon for a given job.

We have considered certain aspects of weapons selection, principally in terms of high-explosive bomb-fuze combinations for various types of targets. In this chapter we are concerned with the whole process of weapons selection—with its underlying as well as its immediate considerations.

75. The Need for Weapons Selection

Air weapons available during World War II were not always properly selected and used. The tendency was to strike the enemy with quantity when proper selection of bombs and fuzes would have produced the same or better results with much less effort. In the battle of France, for instance, several hundred medium bombers attacked a number of bridges over which enemy equipment was being moved. The bombers scored direct hits and near misses in nearly every attack, yet enemy traffic continued to move across the bridges. Should more and bigger bombs have been used? Analysis revealed the answer: the bombs were incorrectly fuzed. Fuzing errors of only a fraction of a second resulted in minor damage instead of broken spans. These

bombing operations cost millions of dollars and took a heavy toll in men and aircraft, but little was accomplished. Such examples of total loss of effectiveness are rare, but all air forces have suffered in varying degrees from inadequate methods of analyzing target vulnerability and selecting weapons and fuzes.

Today the effects produced by our weapons are better understood. We are now faced with the problem of obtaining the utmost from the capability of each weapon. As a nation, we must carefully conserve our severely depleted resources which once seemed limitless.

76. Responsibility for Weapons Selection

Problems of weapons selection are solved at almost all command levels. We have seen that if there are major political considerations in a choice of weapons, the President of the United States may make the decision.

An example at the other extreme might be a fighter pilot who spots an enemy tank and must decide whether to hit it with his two remaining rockets or a burst of 20-mm. ammunition. He decides to fire the rockets and save the gun ammunition for possible enemy opposition before he gets back to his field. It is a split-second decision that rests with him. But does it really rest with him? If his plane had been armed with *all* rockets or *all* machine guns, he would not be faced with this choice. His plane, however, is armed with both. Therefore, he must act within the limits of a previous decision—made at squadron or perhaps wing level—affecting the loading and arming of his plane. Behind that decision lay decisions made at the level of the numbered air force

which allocated ammunition to units. Those decisions in turn were based upon decisions made in view of the logistics problem of a whole theater. Still higher decisions, made in the Pentagon and subject to review by Congress, had reached into American factories and mines to set production quotas for aircraft rockets and gun ammunition.

Of course, the example just given is an oversimplified statement of the problem from the standpoint of logistics only. Many other factors in weapons selection demand high-level consideration. A wing staff, for instance, may not be equipped to study all the target analysis factors that go into weapons selection. Engineers and other experts who can do this might be found at higher headquarters, ranging from the numbered air force to Headquarters USAF. On the other hand, weather and certain other operational factors may enter into the picture at the last minute and result in a selection of weapons at wing level—within the limits set by higher headquarters where the target and other factors were considered.

In solving the problem of weapons selection, there are no chronological steps in a fixed process undertaken by one staff of officers. Instead, a wide variety of factors are considered simultaneously at different levels. And the solution is a cumulative decision of more than one command level, each level setting certain limits within which the lower can act.

Although there are no chronological steps in weapons selection, the factors involved follow a basic problem-solving pattern. Nor is weapons selection strictly a straight mathematical problem to be solved by the use of equations. Of course, there are computations of weapons effects and force requirements, but many uncertain factors enter into each problem. In the final analysis nothing can substitute for good judgment and common sense. The basic steps in the selection process, as in problem solving, are recognizing the problem, gathering data, listing possible solutions, testing solutions, and selecting the best solution.

77. Recognizing the Problem

As applied to weapons selection, recognizing the problem simply means understanding the mission. What is the ultimate objective? This is the important consideration in choosing any weapon. Destruction in itself is rarely a goal, and indiscriminate destruction does not always constitute an advantage gained. The facilities now in enemy hands may soon be needed by our own forces. In such cases, neutralization of the facilities, or short-term disability, may become the goal. An operation in World War II illustrates this point. The bridge over the Rhine at Remagen was put out of commission by our bombers late in 1944 but was not destroyed. German repairs completely restored the bridge just in time for our forces to seize it in March 1945 for the Allied crossing of the Rhine.

The ultimate objective of all bombing is to deprive the enemy of the means of waging war. Whether long-term or short-term damage or neutralization is desired may depend, among other things, on the phase of operations. During the early stages of the conflict, long-term damage or neutralization is usually the objective of strategic bombing. We may wish to extend, as far as possible, the time required by the enemy to resume operations. In that case, total destruction of an industrial complex by an atomic bomb might be appropriate.

Aside from the physical effects of weapons, other considerations may enter into the selection of weapons. Does the relative importance of the target warrant the expenditure of an atomic bomb from our limited stockpile? Will another type of weapon produce a more desired psychological effect on the enemy? One weapon may tend to produce an attitude of defeatism where another might arouse a resolution to fight to the finish.

A thorough understanding of the mission is the major consideration in weapons selection; indeed, it may in itself dictate, or at least limit, the weapons to be used.

78. Target Analysis

The next step in the problem-solving

process is gathering data. This is a broad area of consideration since many factors influence weapons selection.

If the first step is to understand exactly what we are trying to do, the second step would logically be to determine the object of this action. In other words, we must analyze the target.

Analysis of most bombing targets, such as industrial plants and city areas, falls into two phases: functional analysis and physical vulnerability analysis.

Functional Analysis. The purpose of functional analysis is to identify the functions performed by the various parts of the target and to designate those sections of the plant which are vital to its operation. In an industrial target, for example, the various sections of the plant are identified according to the industrial process carried on in them. Functional identification is used in deducing the nature of the machinery, equipment, and other contents of the building. It is also helpful in making the physical vulnerability analysis.

Physical Vulnerability Analysis. The purpose of the physical vulnerability analysis is to provide all the information necessary for establishing the over-all vulnerability of the target. It determines types and over-all dimensions of structures and equipment, materials of construction, number of stories of buildings, size and location of fire divisions and firebreaks, and other pertinent facts. Such analysis for most types of targets has already been accomplished and translated into damage criteria for use in atomic bombing by the Air Force. This preanalysis is possible because the great destructive power of the atomic bomb nullifies small differences between targets of the same type. This is not true, however, with other munitions. For example, incendiary bombs are generally many times more effective per ton in damaging the combustible portions of a target than are high-explosive bombs. For that reason, intelligence that a particular target has some combustible sections can materially influence the selection of the weapon to be used.

79. Determining the Immediate Objective

By means of target analysis we can determine the immediate objective of a bombing attack. This is essentially the process of locating the most vulnerable and vital component of a target—that component against which the attack should be directed in order to accomplish the mission with the least effort. The immediate objective may vary according to the different weapons being considered. For example, suppose a steel plant is the target, and long-term loss of production is desired. This could be achieved by placing an atomic bomb so as to obliterate the whole plant. Or it could be done with high explosives by destroying an essential component, such as the coke ovens, which are easily damaged, are usually grouped together in large horizontal areas, and normally require eight to twelve months to replace. It is possible that chemical attack could effectively stop production by incapacitating the skilled operating personnel. In this case, the immediate objective might not be any portion of the steel plant itself but an adjacent housing area. Thus, the immediate objective for each type of weapon under consideration would have to be selected.

Deficiencies in the economy of an enemy nation may influence the choice of the immediate objective. In the strategic bombing of German aircraft engine plants, for instance, the destruction of buildings was usually more decisive than damage to machinery because the latter was readily replaceable from Germany's surplus stock of machine tools. Against the same target system in Japan, the machinery was the most desirable immediate objective because both the supply of machine tools and facilities for their manufacture were inadequate. Thus it is possible that two plants, while essentially identical in their physical aspects, could represent different immediate objectives and require the use of altogether different weapons and fuzes in order to achieve the same goal with a minimum of effort.

80. Operational Factors

So far we have considered factors in weapons selection which are related to the target. The choice of weapon and fuze may hinge, as we have learned, on ultimate objectives (based on desired results) and on immediate objectives (based on target analysis which indicates vital and vulnerable areas). But we are not finished with the data-gathering phase of our problem-solving process. Now we must consider another set of factors. These are the operational factors, that is, the conditions under which the job must be done.

These operational factors determine the relative ease or difficulty with which various weapons can be placed on the target. They may even outweigh the advantages of one weapon over another. Some weapons can be carried in larger loads per aircraft (in terms of weight and/or effectiveness) or can be aimed with greater accuracy than others and therefore can be placed on the target with less effort. However, no weapon should be considered unless it is capable of effecting the desired damage. The evaluation of these factors requires a complete understanding of the operational aspects of bombing and a thorough knowledge of the operational situation.

Bombing Accuracy. Operational factors strongly affect bombing accuracy, which in turn strongly affects choice of weapons. The immediate objective of an attack will often depend on the expected bombing accuracy. For instance, in conducting a high-explosive attack against a vital unit of a plant, the goal can be achieved either by destroying this unit or by inflicting general damage on the entire plant.

Let us assume that this vital unit consists of heavy machinery and that it can be destroyed by a 3,000-pound bomb fuzed to explode below the roof but above the floor of the building in which the machinery is housed. If the expected bombing accuracy is high, this weapon and method would be the most economical to use.

However, if the actual bombing accuracy is low, what might happen? The heavy high-explosive bombs, falling wide of the

mark, might still cause some damage within the plant area. In all likelihood, however, there would be overdestruction at unimportant points. These heavy bombs would dig craters in the ground, tear up a few hundred feet of roadway or railroad siding, and smash windows, but the buildings themselves would not collapse unless they were hit directly. More important is the fact that, since the capacity of the bombers is limited, the supply of bombs would soon be exhausted and the mission necessarily abandoned.

Now suppose the operational factors have been considered well and it is known beforehand that expected bombing accuracy will be low. Perhaps the mission can be postponed until conditions are better. On the other hand, the timetable may not allow this delay. It will be necessary, then, to choose the weapon that suits low-accuracy conditions. The planes will be able to carry $4\frac{1}{2}$ times more 750-pound bombs than 3,000-pound ones. While expected accuracy might not be good enough for singling out special buildings, it would be good enough (perhaps with the help of radar) for placing the bombs somewhere within the plant area. The general damage to the plant would be much greater because of the number of hits, thus extending the time required for the enemy to put the plant back into operation.

The hypothetical example is not intended to imply that a larger number of smaller bombs should always be used when expected accuracy is low. In some instances heavier bombs might be effectively employed with low accuracy. There might be conditions where incendiaries would be a good low-accuracy weapon, and other conditions where high accuracy would be needed to hit a vulnerable tinderbox. Operational factors, then, tie in directly with functional and vulnerability factors. Which of these factors are related to weapons selection?

Method of Attack. One set of operational factors concerns the relation of choice of weapons to the method of attack. These

factors include altitude, axis of attack, type of formation, and obscuration of target.

1. **Altitude.** The altitude of attack is defined within limits set by the type of attack. However, the altitude employed within these limits affects weapons selection in many ways. Other things being equal, as the altitude increases, bombing accuracy decreases, the potential bomb load becomes smaller, the striking velocity of the bombs is higher, and the angle of impact is more nearly vertical. These results are of lesser importance in the use of the atomic bomb which must be released from very high altitudes for the safety of the aircraft, and in the air burst of chemical munitions in large aimable clusters from which the smaller individual containers are scattered. However, in the use of high explosives, these results are important. Since striking velocity and angle of impact change with altitude, the choice of fuzing to detonate the bombs at predetermined levels within the target will depend on the bombing altitude. Because of this variance in striking velocity and angle of impact, the effectiveness of fragmentation bombs is influenced considerably by altitude of release. The fact that smaller bombs do not usually have satisfactory trajectories limits their use at high altitudes. The altitude is particularly significant in the use of weapons which are effective only if resistant material is first perforated. Consider, for example, a medium-altitude attack against a gun emplacement protected by a concrete slab five feet thick. If the bombing altitude was 10,000 feet, a 1,600-pound armor-piercing bomb would be required to perforate the slab; from an altitude of 15,000 feet, the 1,000-pound semi-armor-piercing bomb would be adequate. The ability of general purpose bombs to withstand impact on resistant materials, such as heavy armor plate and massive concrete, without rupturing or detonating prematurely, depends primarily on their striking velocity and the altitude of release.

2. **Axis of Attack.** The axis of attack with reference to the target can considerably affect the vulnerability of the target. For ex-

ample, the vulnerable area of bridges often can be more than doubled by the axis of attack perpendicular to the bridge. On the other hand, for low- and medium-altitude glide and dive-bombing attacks, the probable errors in range usually far exceed those in deflection. For such attacks, if other operational factors permit, bombing accuracy may be increased by attacking in a direction parallel with the long axis of the target. The orientation of the axis of attack in influencing accuracy must also influence the choice of weapons.

3. **Type of Formation.** The type of formation flown by the attacking force affects the results of pattern bombing for high-explosive or chemical munitions. The type of formation will determine the aiming point relative to the mean point of impact so as to get the desired density of bombs on the objective. The type of formation also will determine the normal dispersion of bombs on the target and the shape of the bomb pattern. Since the bomb density is affected, the choice of munition may also be affected.

4. **Obscuration of Target.** The first bomb dropped on a target sends up billowing clouds of smoke, dust, and debris. As succeeding units attack, the increasing obscuration of the target usually causes a sharp falling off in bombing accuracy. In addition, the concentration of large forces in the vicinity of a target often results in traffic congestion and interference and a further loss in accuracy. Loss of accuracy, of course, must be compensated for in the choice of weapons.

Enemy Defenses. Fighter interception, antiaircraft defenses, smoke screens, and decoys all affect weapons selection and force requirements by reducing bombing accuracy. They further affect force requirements by preventing aircraft from reaching the target, or by spreading the elements of the attacking force.

Aircraft. Other operational factors are related to the aircraft that carry and deliver the weapons.

1. **Type.** No bombing aircraft has yet been designed which can accommodate the

same maximum load of all the various types of bombs. Bomb-bay space limitations and bomb-hook arrangements permit heavier loads of some bombs than of others. The B-45 has rack space for only two of the old type 4,000-pound light case bombs as compared with fourteen 1,000-pound general purpose bombs. If the other operational conditions (length of routes to and from the target, flying altitudes, weather, and runways) are such that a seven-ton bomb load is not excessive, the 4,000-pound bombs require almost 75 percent more effort per ton to deliver than the 1,000-pound bombs. Under these conditions, the 4,000-pound bomb would have to be at least 75 percent more effective per ton on the target to warrant its use.

2. **Ground Speed.** The ground speed of the bombing aircraft affects the accuracy of the bombing, the angle of impact, and the striking velocity. It has much the same influence on weapons selection as has the altitude of attack.

3. **Length of Routes and Runway Conditions.** Frequently, the maximum bomb-stowage capacity of the bombing aircraft cannot be utilized because of weight limitations imposed by the length of the routes to and from the target and the length and condition of the take-off runways. The advantages derived from bomb-stowage capacity of the aircraft may be partially or entirely cancelled in attacks on long-range targets or in the use of short or poorly maintained runways. For this reason the bomb selected for a nearby target may not be the same as that used against an identical, though more distant, target.

Radar Bombing. Radar bombing affects not only the choice of approach, initial point, and aiming point, but also the bombing accuracy of the attack. Radar accuracy will be further affected by the types of equipment used and its maintenance, by enemy countermeasures, and by the training level of crews.

Weather Conditions. Finally, the weather is an important operational factor affecting choice of weapons.

1. **In Loading.** Adverse weather en route

and over the bases at the time of take-off can alter the loading factor by reducing the maximum weight of bomb load that can be carried. Poor visual conditions over the target reduces probable bombing accuracy and thus affects the selection of immediate objectives and aiming points. This in turn means the selection of weapons other than those which would be used under good visual bombing conditions.

2. **In Selecting the Target.** A forecast predicting a probability of adverse weather over the target usually requires planning for one or two alternative actions. One recourse is the use of an alternate and less accurate aiming technique. This may require assigning two sets of aiming points, the conditions encountered to determine later the use of one or the other. The necessity of being prepared to use either may dictate a compromise weapon or one best suited to the condition most likely to occur. Another recourse is to attack a secondary target. The weapons to be used will depend on the importance of this target, as compared with the primary, and on the probability of carrying out this alternate mission. The use of a compromise weapon which would be reasonably effective on either target may be advisable. However, the latest radar equipment should reduce considerably the necessity of bombing a secondary target in case of unexpected weather developments over the primary target.

3. **In Chemical Warfare.** The weather conditions at the target may preclude the use of chemical weapons altogether. The factors discussed under "Micrometeorology" in Chapter 3 explain this limitation.

Other Operational Factors. There are other operational factors which may affect the problem. Among these are dud probability, relative aimability of bombs, number of aircraft required for a mission, abort rate, etc.

81. The Weapons Themselves

So far our discussion has been concerned with target selection and with operational factors that might affect any flying mis-

sion, regardless of the weapons used. It should be clear, however, that these factors tie into the selection of weapon and fuze. The decision is affected by certain factors which are related to the weapons themselves. The special characteristics of the weapons, as well as their capabilities and limitations, have been discussed in previous chapters. Our concern here is with underlying factors.

For instance, the availability of the weapons is a point to consider. It is logistically unsound to stockpile sufficient quantities of all sizes of all types of weapons, particularly at overseas bases. A shortage of production capacity or national resources may limit the available supply of certain types of weapons. Consequently, shifts in target priorities will often reveal shortages. The problem of supplies on hand may have to be considered in the selection process. The weapons required for the high-priority targets may have to be conserved by using second choice weapons on less important targets.

Further, there should be an assessment of the psychological implications of each weapon under consideration. We should seek to obtain the maximum psychological effects possible consistent with mission accomplishment.

At times political considerations arise. For example, certain weapons may be restricted because of national policy. Or, in driving the enemy from occupied territory which we plan to liberate, we must avoid taking action which would antagonize the local population and thus complicate our task of occupation. This problem was with us before and during the liberation of France in World War II, and it affected our choice of bombs dropped on French soil. It is generally agreed that if the atomic bomb had been available then, it would not have been dropped on France. Nevertheless, the heaviest high-explosive bombs of that time were used against German submarine pens in French ports. It follows that there might be similar occasions for using massive high-explosive bombs in future wars.

Such matters may influence weapons selection in the field, but usually the decisions are made at high level, and reach field units in the form of directives or policies.

Another factor which may be considered in weapons selection is the cost, either in dollars or in terms of national resources. This is consistent with the aim of mission accomplishment with minimum effort and risk.

82. Making the Choice

Let us return now to our basic problem-solving procedure. How far have we come with it? First we learned that recognizing the problem consists of determining the ultimate objectives for bombing missions. The next step is gathering data, or listing factors that come under three categories: (1) the target and the immediate objective, (2) operational factors that affect the performance of the mission, and (3) the cost and political expediency which pertain to the use of the weapons.

The next step is to list possible solutions. After having determined the conditions which affect our mission, it is logical to propose the weapons which might feasibly accomplish it. Knowledge and experience will dictate that many of the weapons in our arsenal should not be considered further in the light of the objective of the mission and known operational conditions. As a matter of fact, detailed analysis and comparison would be necessary for only a few of the possible alternatives.

The detailed analysis corresponds to the next step in problem solving, testing solutions. Fortunately, effects of weapons can be computed mathematically to determine the weapon within each category which will produce the desired results most economically. We have seen, for instance, that the effects of high-explosive bomb-fuze combination are measurable, as are the effects of atomic bursts or chemical weapons. What remains, then, is the question of which basic weapon to use, and here precise yardsticks are lacking. Here common sense and judgment are used to great advantage.

This comparison of weapons leads to the final step, the selection of the best solution. In considering all factors involved, the application of statistical methods to the weapons delivery problem helps planners to arrive at the best probability for successfully completing the mission. However, the weapon which offers the best chance for success is not always the most desirable, perhaps because of political reasons, or critical shortages, or uncertainty as to recuperative time, etc. Weapons selection then becomes a matter for command decision.

SUMMARY

THE PROCESS OF WEAPONS SELECTION may be outlined according to the five basic steps of problem solving: recognizing the problem, gathering data, listing possible solutions, testing solutions, and selecting the best solution. Although weapons selection can be outlined as a problem, it cannot be thought of as a single problem to be solved according to a set procedure by a group of officers at one headquarters. More than one command level may work on aspects of the problem simultaneously. Specialists may be called upon to contribute their knowledge and experience.

Weapons selection requires a knowledge of the following subjects: (1) structures and all types of industrial, communications, and military equipment. This knowledge helps in determining the vulnerability of various kinds of targets, in predicting the reaction of structures to the action of bombs, and in exploiting the inherent weakness of structures. (2) The capabilities and characteristics of weapons and fuzes of all types. It is important to know the effects of all types of weapons and fuzes on structures, equipment, and personnel. (3) The

operational aspects of bombing. Formation flying, size of force, weather conditions, quality of enemy opposition, the effect of altitude on accuracy, and other potentialities and limitations of bombing techniques strongly influence weapons selection and force requirements.

It can be seen, also, that weapons selection involves a complex set of ever changing and interrelated factors. The proper interpretation of these factors demands highly trained personnel. A knowledge of mathematics is a step in the right direction, but sound judgment is also essential. Many factors must be considered simultaneously. Therefore, no formulas or step-by-step procedures will answer. However, this may be taken as a rule of thumb: the goal of weapons selection for a particular attack is to choose the weapon that can accomplish the mission with the least over-all cost in terms of effort, risk, and national resources.

REVIEW QUESTIONS

THESE QUESTIONS relate to a single problem: A steel mill is located in an allied country under enemy occupation. It is producing vital war materials for the enemy. At some future time, perhaps in a year or two, we hope to recapture the plant.

1. What would be the ultimate objective in attacking this plant?
2. Assuming high bombing accuracy, what would be the immediate objective?
3. According to data presented in the first chapter, what bomb-fuze combination would accomplish this immediate objective?
4. How might weather conditions affect choice of weapons in this case?

Answers To Review Questions

CHAPTER 1

1. (a) 80 percent; (b) 50 percent; and (c) 67 percent.
2. A high-explosive light-case bomb is designed for maximum air blast. It is fuzed to explode on, or before, contact. If it were used against a tall, steel-framed building, it would explode on the roof, causing only a small amount of damage to the floors below.
3. In a steel mill, coke ovens are the best target because they are vulnerable to both direct hits and nearby bursts; because many months are required for their reconstruction; and because damage to any one main component of a steel mill can severely impair the operating efficiency of the other parts.
4. Addition of a cone-and-blade fin to an old type bomb greatly improves its accuracy, but it does not overcome all deficiencies. The newer type fin adds to the size and weight of the bomb without increasing its power.
5. An electrical connection on the side of the bomb contains a device which prevents the fuze from arming until several seconds after the bomb has started to fall.

CHAPTER 2

1. A high-muzzle velocity is desirable to reduce time of flight, which, in turn, reduces errors caused by gravity drop and windage.
2. A high-speed aircraft must make a much longer run on its target than would a relatively slower aircraft; therefore it must begin firing at a greater distance, and it needs longer range projectiles. Bullet density in a target area is also decreased by the speed of the aircraft, making a higher cyclic rate necessary.
3. No. A relatively low-muzzle velocity is acceptable in defending a bomber from the rear. In this case the target (the attacking enemy fighter) is coming into the bullet pattern. Projectiles fired from the tail gun are given added velocity by the relative wind.
4. The first rammer pushes the cartridge half way into the chamber; the second rammer completes the chambering. Thus the reciprocating parts travel only half the normal distance and a higher cyclic rate is possible.
5. It is detonated by the nose fuze Mark 149, but it must also carry, unarmed, the base fuze Mark 159, for safety. The rocket must never be fired without having the base fuze firmly in place;

otherwise the propellant gases will contact the explosive filler and detonate the head during launching.

CHAPTER 3

1. The President or the Joint Chiefs of Staff have command responsibility for initiating the use of toxic chemicals.
2. Micrometeorology is the study of the influence of terrain upon weather in a locality.
3. The plasticized white phosphorous bomb produces a dense white smoke which can be used to blanket enemy positions. It is also effective as an antipersonnel weapon because fragments of the material can produce severe burns. In a limited way it has incendiary effects.
4. The toxic chemical GB is classified neither as one nor the other, but as a persistent nonpersistent agent. Exposed area should be flushed with water. Each gas mask carrying case is equipped with a syrette for self-administration of an atropine compound. If taken soon enough after exposure, this injection will diminish the toxic effects of the gas.
5. Chloride of lime, lye, strong soap, and washing soda are effective decontaminating agents, but they corrode the machined metal in gun breeches. On such surfaces a noncorroding issue preparation (DANC) should be used instead.

CHAPTER 4

1. Antigens are substances produced by invading microorganisms which cause the host to produce antibodies to resist the infection. Sometimes immunization can be achieved by separating antigens from the harmful parts of a germ culture and injecting them into the potential host. The host thus builds up antibodies and resistance to the disease before infection occurs.
2. The requirements that all biological agents must meet include:
 - a. Capability of producing a significant percentage of incapacitation or death in the target.
 - b. Economical production in adequate quantities to permit employment on a mass scale.
 - c. Sufficient stability in storage, in transportation, and after dissemination to insure virulence.
3. There is no feasible method of eradicating stem rust in infected cereals. Rust-resistant strains of cereal can be planted. Also helpful is the elimination of the barberry bush, an intermediate host.

4. The danger of infecting our own troops and the delay in causing sickness among enemy personnel would limit the tactical use of biological warfare.

CHAPTER 5

1. Wood was burned in an enclosed space. Before it was burned, the total mass of air and wood was measured. The weight was compared with that of the air and ashes afterward. There was no difference in two masses. Matter was not destroyed when the wood burned.
2. An atom is made up of protons and neutrons in the nucleus, surrounded by orbiting electrons.
3. This is the chemical symbol for an atom of uranium. It indicates that this atom has an electric charge of 92 (92 protons counter-balanced by 92 negatively charged electrons). The figure 233 stands for the mass number of atoms. Since only protons and neutrons make a significant contribution to the mass, the number of neutrons must be arrived at by subtraction ($233 - 92 = 141$). There are 141 neutrons in the atom. The uranium atom is unstable. It begins to decay by firing off an alpha particle, which reduces its mass to 229 and its charge to 90, making an isotope of thorium (${}_{90}\text{Th}^{229}$). Since this isotope is also unstable, the decay process continues until a stable isotope of lead is reached.
4. Particles in the nuclei of some atoms have more weight than the same number of particles in the nuclei of other atoms. When certain atoms having a relatively high average mass per nuclear particle can be split to form atoms of the type that have less average mass per particle, the total difference in mass is converted into energy.

CHAPTER 6

1. When an atomic bomb explodes in the air, a powerful shock front forms on the outside of a rapidly expanding fireball. About .015 second after the instant of detonation, when the fireball is about 600 feet in diameter, the shock front breaks away from the fireball, which continues to expand more slowly. This is known as the *breakaway*. Part of the shock front strikes the earth and is reflected back into the air, where it catches up with the main shock front and the wave is thus increased in power two to eightfold. This effect is called the *mach wave*, or *mach stem*.
2. The effect would be moderate damage, basically defined as damage sufficient to prevent useful military function until extensive repairs are made. In this case it would involve structural damage. These data are derived from using both Table 9, which puts 2,600 yards within the 5 p.s.i. overpressure range for a 40-kiloton bomb.

3. In an air burst, residual radioactivity is negligible. One hour after a surface burst it would be possible to work in the area for short periods of time. One hour after an underground burst the area would be virtually untenable, with a radioactivity rate of 2,000 roentgens per hour. The area surrounding an underwater burst would be similarly contaminated one hour after the burst.
4. The base surge is a cloud of dust or moisture, highly radioactive, expanding along and billowing upward from the surface after an underground or underwater burst.
5. An air burst would not be an effective way to contaminate an area since it deposits no residual radioactivity. Yet, the air burst covers the widest area. A surface burst would temporarily blanket a fairly wide area with radioactivity, thus detaining a possible enemy advance by a matter of hours or, at the most, a few days. The more intensive contamination resulting from underground bursts would be confined to limited areas, which the enemy could probably bypass.

CHAPTER 7

1. During a cold war the military uses of atomic energy, of course, have top priority. To date this has meant that about ninety-nine percent of the fissionable materials available has gone into making atomic bombs and only about one percent has been used for civilian purposes. As long as atomic materials remain scarce, use of atomic energy for civilian purposes will be severely limited. This situation may be eased in the future by discovering and developing new sources of atomic raw materials. Also, there may be developed breeder reactors and other ways of increasing the yield of fissionable material.
2. At the top level, a Military Liaison Committee, composed of generals and admirals, brings about coordination between the Department of Defense and the Atomic Energy Commission. The Atomic Energy Commission's principal direct link with the armed forces is provided by the Santa Fe Office of Operations in the Sandia Corporation, which operates a laboratory at Sandia Base and works closely with the field command of the Armed Forces Special Weapons Project and the Air Force Special Weapons Center.
3. The logistic problems of atomic warfare are greater than those of conventional warfare for the following reasons: small quantities of many items are called for in atomic production and testing, creating a demand for very strict control; a high degree of training is needed to maintain quality control; units must be made ready so that they are capable of assembling atomic weapons anywhere on earth; and atomic materials are in short supply.

4. In World War II, reconnaissance planes often were not molested because they operated alone over enemy territory. One plane did not pose a serious threat. In atomic warfare, however, one plane will probably trigger the enemy's air defense system as quickly as would a whole formation.
5. Visibility as such is not a factor. The *cause* of low visibility—moisture and dust in the air—reduces the range of thermal radiation. Since the range of thermal radiation exceeds that of blast and nuclear radiation, reduced visibility means a lower safe-release altitude for an atomic bomb.

CHAPTER 8

1. The ultimate objective would be to halt production for about a year with only partial destruction of the plant and a minimum of human casualties.

2. Functional and vulnerability analyses of steel mills indicate that the coke ovens are both vital and vulnerable and would probably be the best target within the plant area.
3. The 1,000-pound general-purpose bomb with an .025-second delay fuze. Of the newer bombs, the 750-pound bomb would probably be the best choice.
4. Weather conditions might reduce accuracy to the point where there would be little chance of hitting the coke ovens, but hits within the entire mill area would still be possible. A compromise weapon that would do the most general damage would be selected. Perhaps this would indicate the use of a larger number of smaller bombs. However, other factors not discussed in this chapter would affect the choice and make a clear-cut answer impossible here. Adverse weather might also reduce the bomb capacity of the aircraft used.

